AUGUST 1958

THE WELDING JOURNAL

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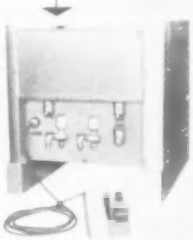

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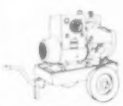
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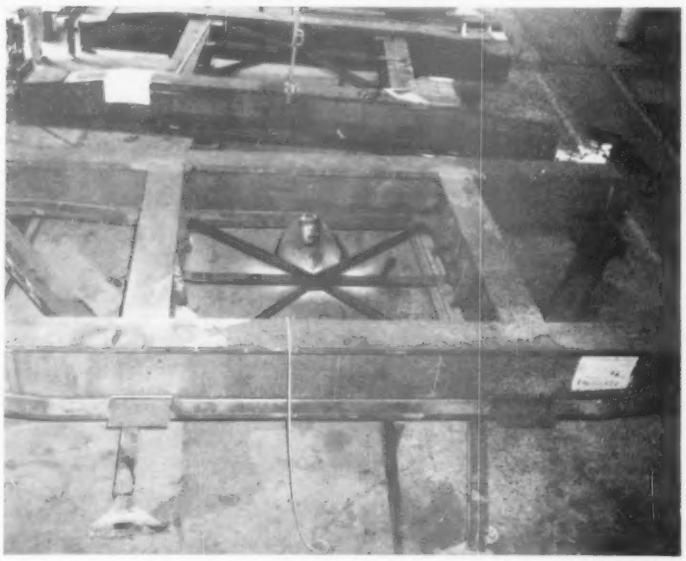

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AWS PROGRESS AND PROGRAM

There are 12,425 individuals, by a recent count who are, or should be, interested in what the AMERICAN WELDING SOCIETY is "doing," what it is "trying to do" and what it "should be doing." These are the members whose dues and whose interest make the SOCIETY a going concern.

Evaluating the SOCIETY program in the "doing" phase is easy by looking at the record. Everyone knows the SOCIETY is publishing a JOURNAL, producing a HANDBOOK and studying and printing standards and specifications. Moreover it is producing a Welding Show together with annual and local section meetings. These integrated activities are far in advance of any other welding program in the world.

These activities do not just happen. They require a great deal of contributed effort and staff work. We have an efficient staff and an energetic one. Our meetings are sometimes crowded by the lack of adequate hotel facilities and this places an extra burden on the local section and the national headquarters' people. On the whole, we are meeting our responsibilities.

In evaluating the "trying to do" phase, the SOCIETY has two new programs in the development stage to meet needs that have been discussed for many years. One of these is in the educational field where the program has been revitalized and placed in the hands of an Educational Activities Committee.

This group came into being in answer to pressure to interest young men in opportunities in the welding industry and to introduce welding to all students particularly in engineering. It is apparent that the need existed in view of the fine reception to the efforts so far.

The SOCIETY also recognizes that the importance of welding must be made clear to the public. A new department to do this is being organized and will try to develop an aggressive program. It has been our habit in this industry to tell each other of the fine things we are doing. The need is recognized that this is good, but only a share of the job, perhaps a very small share.

The effort in both Education and in Information is a starter and a modest one because the SOCIETY is carrying the financial burden without outside help or assessment. Nonetheless, it shows an aggressive spirit in tackling new and perhaps difficult fields.

In evaluating the "should be doing" phase, one can get almost as many opinions as members. One need which has been expressed, but has not been agreed upon, concerns membership. The need for recognition of engineering achievement in the welding field by membership grade requirements is one of these phases. Perhaps we are inconsistent in urging specialization in welding engineering in colleges and universities when we do not recognize these requirements in any membership grade. Benefits in prestige and recognition accrue to members of engineering societies and perhaps we owe our members an equal opportunity.

Hundreds, perhaps thousands, of SOCIETY members are active in helping to arrange and conduct SOCIETY affairs. From these men will come our future policies. In view of the enlightened and aggressive program which they have made, we need not worry about the future of our SOCIETY.

G. O. Hoglund
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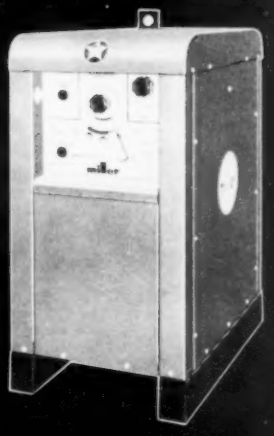

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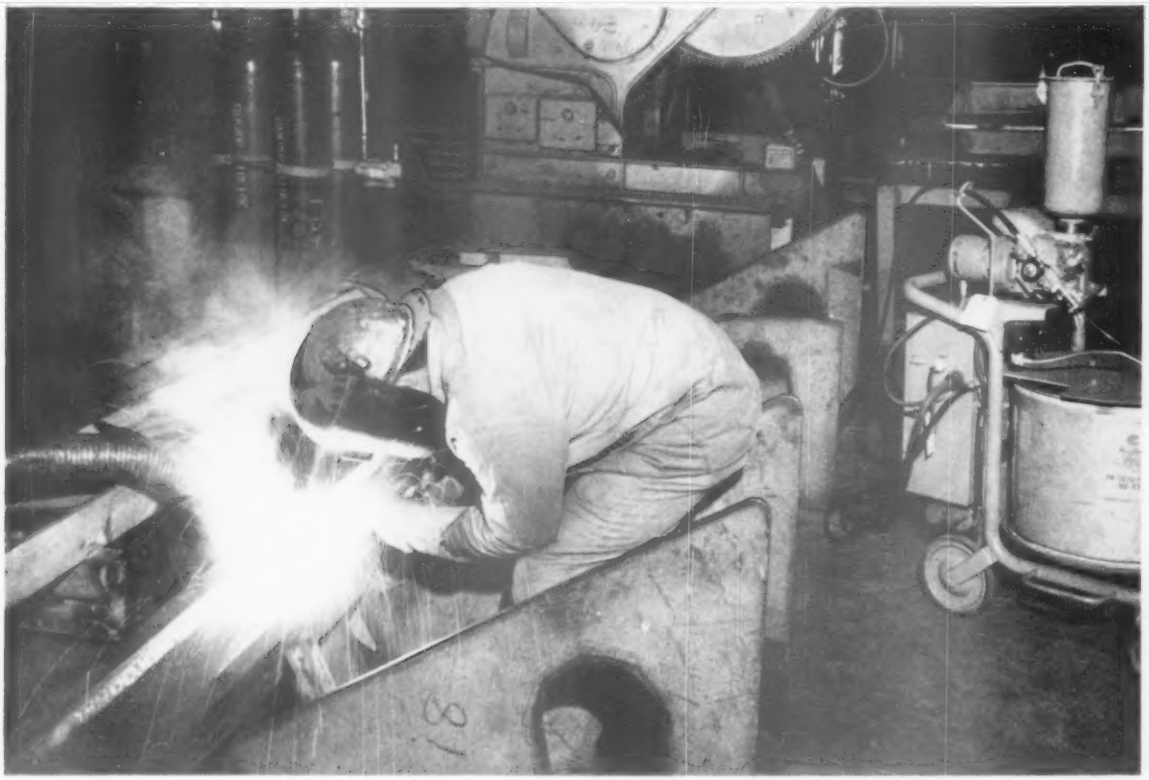


Fig. 1 Application of magnetic-flux welding to heavy I-beams

INDUSTRIAL APPLICATIONS OF MAGNETIC-FLUX GAS-SHIELDED ARC WELDING

A number of production applications is described and the economical and technical advantages of the process are summarized

BY R. T. TELFORD AND F. T. STANCHUS

INTRODUCTION. In 1957, a new process to weld mild steel was introduced after five years of research and development, and over a year of field testing and evaluation. This new process is generically termed magnetic-flux gas-shielded arc welding or simply, magnetic-flux welding. During the past year, magnetic-flux welding has been successfully applied to a large number of production jobs. It has demonstrated its ability to increase productivity and reduce costs. The purpose of this paper is to describe a number of different production applications of magnetic-flux welding and to summarize economical as well as technical advantages for the mild-steel fabricator.

R. T. Telford and **F. T. Stanchus** are associated with the Development Laboratory, Linde Co., Newark, N. J.

Paper presented at AWS 1958 Annual Spring Meeting held in St. Louis, April 14-18, 1958.

Process Description

Magentic-flux gas-shielded arc welding is somewhat similar to inert-gas consumable-electrode welding in the sense that both processes employ a continuously fed electrode and a gas shielding. The principal difference is the use of flux with the newer process. Furthermore, the shielding gas used is inexpensive carbon dioxide, not inert argon. During welding, the wire and a suspension of flux-in-gas are fed simultaneously to the torch. As shown in Fig. 2, the welding current flowing through the wire establishes a magnetic field in accordance with well-known electromagnetic principles. The magnetic field causes the magnetizable flux to be attracted to the welding wire. This "flux coating" stabilizes the arc and produces a slag which metallurgically refines and protects the puddle, and influences weld contour and coalescence. About

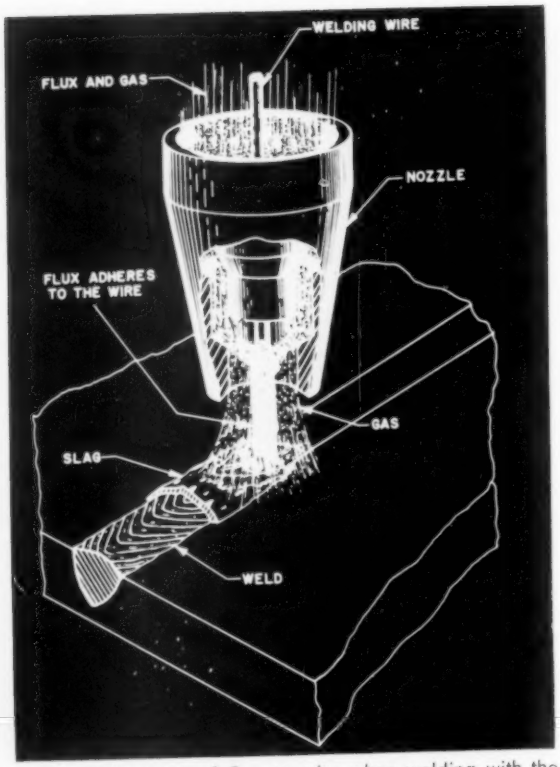


Fig. 2 Adherence of flux to wire when welding with the magnetic-flux process

½ lb of flux per pound of wire is used for most applications. However, this can be varied depending upon the application. In addition to rendering the flux fluid and conveying it to the torch nozzle, the carbon-dioxide gas shields the weld puddle.

Both 3/32- and 5/64-in. diam wire are used commercially with this method. The larger wire is used for most downhand applications (flat and horizontal) on 5/16-in. thick and greater steel plate. The 5/64-in. diam wire is used on lighter materials and for welding in all positions—flat, horizontal, vertical and overhead.

Industrial Applications

Structural Fabrication

One of the earliest and largest applications of the magnetic-flux process has been the fabrication of earth-moving equipment of the types shown in Figs. 3 and 4. Bulldozer blades of many sizes and types, C-frames, cable control housings, scraper bottoms and sides are welded with the magnetic-flux process. Butt, lap and tee fillet, and plug welds made on these assemblies meet high standards of quality and mechanical properties. Welding speeds on these varied joints are in the order of 50% greater when compared with previous covered - electrode procedures. The customer estimates that his cost of welding (welding process consumables, labor and overhead) has been reduced about 30% through the adoption of magnetic-flux welding. In addition, rugged field tests have indicated

Fig. 3 Magnetic-flux-welded bulldozer blade and C-frame on tractor

that welds exhibit improved service performance.

Melting pots used in bauxite reduction plants of the aluminum industry require considerable welding. Some pots are approximately 28 ft long, 14 ft wide and 4 ft high. Magnetic-flux welding is used to prefabricate the pot ends shown in Fig. 5 and other short welds within the pot. Mechanized submerged-arc welding is applied to the long seams. This welding combination improved weld X-ray quality, reduced distortion and lowered costs as compared with covered-electrode welding. In addition to obtaining higher speeds with the new process, the customer took advantage of its greater penetration. He oxygen-beveled $\frac{3}{4}$- and $\frac{5}{8}$-in. thick plate to a smaller double-vee groove joint (45-deg included angle and $\frac{1}{4}$-in. nose). This required considerably less weld metal and permitted welding the joint in two passes.

Multipass welding has also been found advantageous for heavy sections of steel. At one location, for example, valve bodies as shown in Fig. 6 are fabricated from 3$\frac{1}{2}$-in. thick Type A7 steel. Four butt welds are required to form each of the rings. With $\frac{7}{32}$-in. E7016 covered electrodes, preparations of the four welds have required a total time of 24 hr. Magnetic-flux welding, on the other hand, requires only 12 hr. Total time in each case has been based upon normal operating factors. In addition to arc time, total time included the time required for attaching and removing starting and run-off tabs. Total time also included chipping and turning and handling required to position the ring. Magnetic-flux welds were made using $\frac{5}{64}$-in. diam wire at 475 amp DCRP, 31 v, and a flux-to-wire ratio of 0.4. A total of 48 passes was made in each joint shown in Fig. 7. Test welds exhibited excellent mechanical and bending properties as illustrated by Fig. 8.

Large beams are very often fabricated by welding. One fabricator has used the magnetic-flux gas-shielded arc process to make 16-ft long I-beams with a $\frac{7}{16}$-in. thick web and a $1\frac{5}{8}$-in. thick flange (Fig. 1). As a result of welding over 3000 ft of beams, this fabricator has concluded that welding with the magnetic-flux process is 300% faster than welding with E7016 covered electrodes.

Conditions and materials for magnetic-flux welding this application are shown with costs in Table 1. Comparable data for covered-electrode welding are contained in Table 2. Material costs for both magnetic-flux and covered-electrode welding were approximately equal. However, labor and overhead costs per unit were considerably less with the new process because of its greater speed. The total cost of magnetic-

Fig. 4 Scraper after fabrication with magnetic-flux process

Fig. 5 Application of magnetic-flux welding to end of melting pot

Fig. 6 Fabricated valve body with 3$\frac{1}{2}$-in. thick ring formed by four magnetic-flux welds

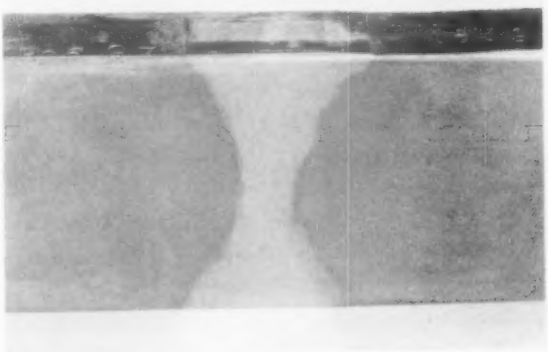


Fig. 7 Cross section of 48-pass magnetic-flux weld in 3$\frac{1}{2}$-in. thick A-7 steel

Fig. 8 Magnetic-flux weld bend and tensile sample (72,000 psi ultimate tensile strength)

Fig. 9 Final product after welding head to shell of low-pressure gas tank with combination of magnetic-flux and submerged-arc welding

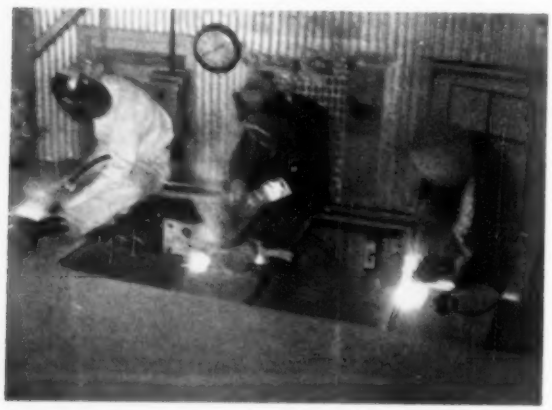
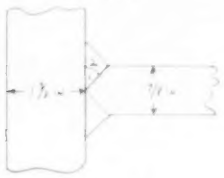


Fig. 10 Three stiffener rings simultaneously welded into place with magnetic-flux process in less than one-third the time required with covered-electrode welding

Table 1—Conditions and Costs for Magnetic-Flux Gas-Shielded Arc Welding of I-beams

Joint



Operating Data

Number of welds	4
Passes per weld	2 with $\frac{5}{64}$-in. diam wire
Total weld length	16.0 ft in. per weld
Arc time	3.64 hr
Total time	10 hr

Welding Costs

	Cost per lb weld metal deposited	*Cost per I-beam*
Wire	$0.17	$11.00
Flux	.14	8.85
Carbon dioxide	.03	1.91
Consumables	$0.34	$21.76
Labor	.39	25.00
Direct cost	$0.73	$46.76
Overhead	.55	35.00
Total cost	$1.28	$81.76

flux welding as applied to these I-beams was, therefore less than the cost of covered-electrode welding as previously indicated.

Tank Fabrication

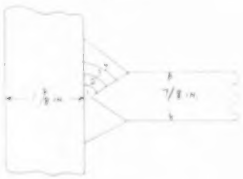
The tank and pressure-vessel fabrication industry is highly competitive and depends upon good welding practices to a large extent to maintain its livelihood. Several fabricators have already qualified both process and operators in the usual manner for ASME boiler code and similar code work; many have adopted the process in conjunction with submerged-arc welding for butt welds in tank stiffener rings, nozzles, flanges and reinforcing pads.

Submerged-arc welding is widely used in fabricating low-pressure gas tanks. On some joggle joints, with the usual fit-up, a manual root pass is required prior to automatic welding. Manual passes on the two head-to-shell joggle joints on the 48-in. diam x 120-in. long tank shown in Fig. 9 required a total welding time of 23 min. When magnetic-flux gas-shielded arc welding was substituted, speed was increased to 31 ipm, and total welding time was reduced to 9 min, thereby substantially reducing welding costs. In addition, the completed joint displayed significantly improved radiographic quality.

On the same tank, three $1\frac{1}{2}$-in. thick stiffener rings are attached by means of $\frac{5}{16}$-in. size fillet welds. Figure 10 shows three operators sitting on a platform on top of a rolled tank and welding the rings simultaneously. In this application, the new method required only one-third the time for covered-electrode welding. Note how the smoothness, uniformity of

Table 2—Conditions and Costs for Welding I-beams with E7016 Covered Electrodes

Joint



Operating Data

Number of welds	4
Passes per weld	Layer 1 with $\frac{5}{32}$-in. electrode (28 v, 190 amps); layers 2, 3, and 4 with $\frac{1}{4}$-in. electrode (29 v, 300 amps)
Total weld length	16 ft 4 in. per weld
Arc time	10.66 hr
Total time	31.3 hr

Welding Costs

	Cost per lb weld metal deposited	*Cost per I-beam*
Consumables	$0.32	$ 19.10
Labor	1.30	78.25
Direct cost	$1.62	$ 97.35
Overhead	1.83	109.55
Total cost	$3.45	$206.90

weld contour and lack of undercutting make the painted weld shown in Fig. 11 appear much like an automatic weld.

When only a few nozzles of a particular size are to be made, the fabricator usually employs manual welding rather than the faster automatic submerged-arc process because set-up time of automatic welding cannot be justified. Because it is easy to set up and establish welding conditions with the magnetic-flux process, it is often used on nozzle fabrication. The $1\frac{1}{2}$-in. thick nozzle shown on Fig. 12 was welded by means of two passes from each side at a current of approximately 450 amp DCRP. The new method was also used as a direct replacement for low-hydrogen type covered electrodes for welding heavy flanges to nozzles as shown on Fig. 13. On both jobs, the combination of high speed and increased penetration proved advantageous to the fabricator.

Double-Lengthening Pipe

Submerged-arc welding is used by pipe fabricators for longitudinal welds in virtually all thicknesses of material. It is also used generally for double-lengthening operations on material of $\frac{3}{8}$ in. thickness and greater. On lighter material, fitting problems are encountered unless good backing is provided.

One fabricator formerly double-lengthened pipe of $\frac{3}{16}$- to $\frac{1}{4}$-in. thick wall and 20 to 30 in. diam by applying an automatic covered-electrode pass followed by a manual iron-powder-type covered-electrode pass in a 60-deg included-angle single-vee full-thickness groove. The joint was backed by means of an expandable line-up copper aligning and backing ring. Each pass was applied at a speed of 19 ipm. Welding in this manner,

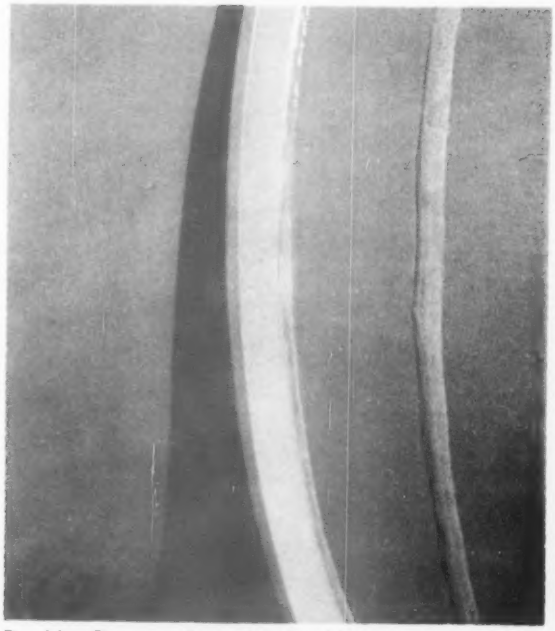


Fig. 11 Close-up of completed weld

Fig. 12 Four-pass butt weld in a $1\frac{1}{2}$-in. thick nozzle made with magnetic-flux welding, using 450 amp

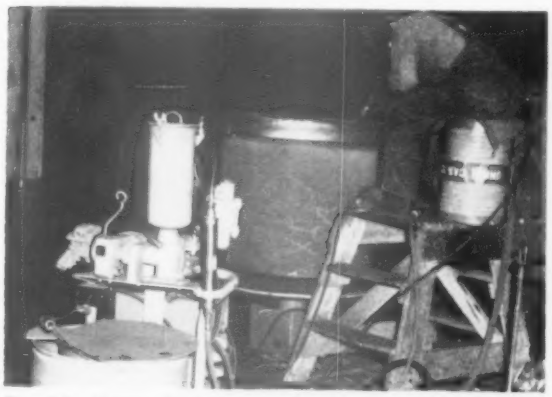


Fig. 13 Heavy flange on nozzle (flange easily attached because of high speed and deep penetration of magnetic-flux process)

Fig. 14 Welding at 42 ipm in $\frac{1}{4}$-in. thick 22-in. diam pipe using hand-guided torch in a holder to produce a square-butt magnetic-flux weld

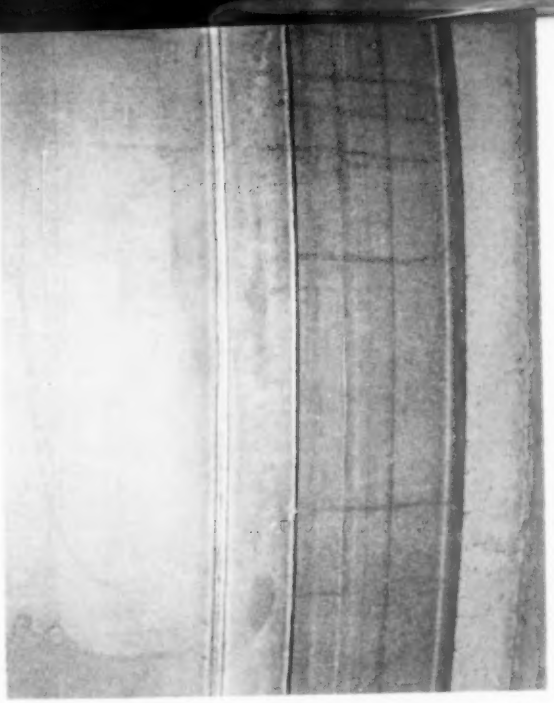


Fig. 15 Mechanized magnetic-flux horizontal lap-fillet weld in $\frac{3}{16}$-in. thick mild steel

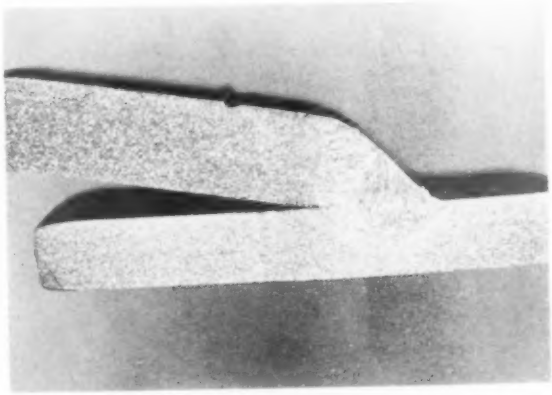


Fig. 16 Sectioned horizontal lap-fillet weld

Table 3—Welding Data for Double-Lengthening Pipe

(27,802 Linear Feet of Welding)

	Square butt	60-deg single vee
	Magnetic-flux gas-shielded arc	Covered electrode
Consumables:	$\frac{5}{64}$-in. diam wire—1853 lb Flux—926 lb Carbon dioxide—5296 cf	$\frac{5}{32}$-in. automatic electrode 8340 lb $\frac{5}{32}$-in. E6024 electrode—5500 lb
Passes:	One pass using 420 amp DCRP	Layer 1—automatic electrode with 425 amp ac Layer 2—E6024 with 315 amp ac
Welding speed per pass:	42 ipm	19 ipm
Arc time:	133 man-hours	586 man-hours

Table 4—Pipe Double-Lengthening Cost Comparison: Magnetic-Flux Gas-Shielded Arc Welding vs. Covered-Electrode Welding

(27,802 Linear Feet of Welding)

	Magnetic flux	*Covered electrode*
Consumables	$ 728	$3572
Labor	266	1172
Direct cost	$ 994	$4744
Overhead	399	1758
Total cost	$1393	$6502

two men produced 99 joints per 9-hr day in 24-in. diam pipe.

Due to the advantageous penetration of the magnetic-flux process, the fabricator adopted it using a square-butt joint at the same expandable aligning and backing ring. Wire was $\frac{5}{64}$ in. diam. Flux-to-wire ratio was 0.5 at a welding current of 420 amp DCRP and an arc voltage of 28 v. Under these conditions, 1725 butt joints in 24-in. diam pipe and 2400 joints in 27-in. diam pipe or a total of 27,802 lineal ft were welded at a speed of 42 ipm. A finished weld is shown on Fig. 14. With this arrangement, one operator produces approximately 125 joints in an 8-hr period compared to the total of about 100 joints previously produced by two operators in 9 hr. Thus on this job, using the magnetic-flux process, one man produced almost as much as three men using conventional

Fig. 17 Use of magnetic-flux process for reparing a locomotive truck frame

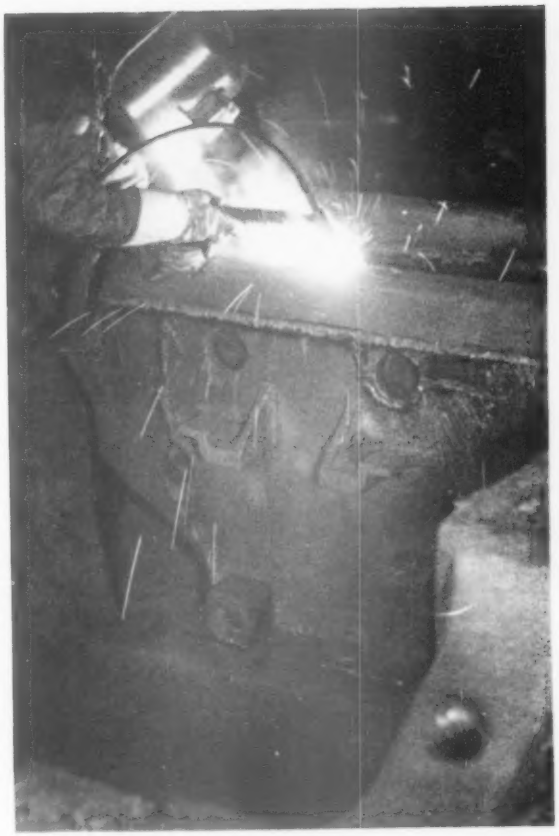


Fig. 18 Repair of large rock-crusher castings

methods. Moreover, leakage was reduced to a new low.

Table 3 provides data covering the welding operation, while Table 4 illustrates cost estimates based upon material and arc-time measurements. Since it was possible to utilize a square butt joint, the cost of materials for the magnetic-flux process was 80% less than the cost of covered-electrode welding. Labor and overhead costs were also 80% less because of greater welding speeds associated with the process.

Pipe Connections

Bell-end rings are often attached to large diameter pipe by means of submerged-arc welding. Sometimes this presents difficulties because fitup is likely to be poor and flux handling is a problem.

One fabricator has solved problems involving the welding of bell-end rings to pipe by using magnetic-flux gas-shielded arc welding. When using this process, 160-in. diam pipe with $\frac{3}{16}$-in. thick wall is rotated around its vertical axis. As the pipe rotates, it is mechanically welded in horizontal position with $\frac{3}{64}$-in. diam wire and a welding current of 240 amp and an arc voltage of 27 v when the speed of welding is 32 ipm. This is more than twice the progression speed obtained with covered-electrode welding.

A finished weld may be seen in Fig. 15, and a photomacrograph of a typical weld section is shown in Fig. 16. All welds are sound and show good coalescence; the finished weld is uniform and has a bright appearance.

Repair of Steel Castings

It is very difficult to produce large steel castings without any surface defects. Common practice is to remove such defects by means of oxygen-gouging and then to weld the gouged area. Welding is most often done in the flat position. However, welding must often be done in other positions.

Where repairs are made in the flat position, $\frac{3}{32}$-in. diam wire has been used with welding currents of approximately 475 amp at a deposition rate of 18 lb per hr. It is not surprising, then, that on occasion, an operator has deposited as much as 100 lb of metal in an 8-hr day. Figure 17 illustrates a repair weld on a railroad locomotive truck frame. In this application, the amount of metal actually deposited at the end of the day has been more than twice as great as that deposited by covered electrodes. This has been equally true for repair welding of large valves and rock-crusher castings.

Wire of $\frac{1}{8}$ in. diam has been used extensively for repairing large rock-crusher castings. Figure 18 depicts welding on top of one of these castings using $\frac{5}{32}$-in. diam wire at a current of about 300 amp. Welding is downhand and the deposition rate is 12 lb per hr. The same welding conditions are used inside the casting. In Fig. 19, the same operator is welding in the vertical position. He uses a reduced current set-

ting of about 200 amp and deposits 7 lb of metal per hr. Measurements conducted over several 10-hr work day shifts indicate that the process actually deposits 60 lb per shift when welding in all positions. This is more than twice as great as previously obtained with covered-electrode procedures.

Repair welding in steel foundries has been concentrated on steel castings which require a minimum weld tensile strength of 60,000 psi when tested in the annealed, normalized or normalized-and-tempered conditions required by the American Society for Testing Materials (ASTM) and railroad specifications. Although production experience has been limited, it appears that inexpensive, slightly alloyed but otherwise standard welding wire will produce welds exceeding an ultimate tensile value of 70,000 psi in the normalized-and-tempered condition required by ASTM A-216 Grade WCB and AAR-M-201 Grade B specifications.

Conclusion

Magnetic-flux gas-shielded arc welding has been successfully used for a variety of applications during the past year. Such use indicates that the process has several advantages compared to covered-electrode welding. These can be summarized as follows:

1. Up to an 80% reduction in costs.
2. Up to a 400% increase in welding speeds.
3. Excellent weld quality, mechanical properties, appearance and lack of undercutting which make it possible to meet even the strictest welding requirements.
4. The use of magnetic-flux welding for root and backing passes as preparation for submerged-arc welding improves weld quality and reduces over-all welding costs.
5. No special technical training is required. Application of the magnetic-flux gas-shielded welding process presents no difficulties for the experienced welder. However, a certain amount of training is required for inexperienced welders.

Bibliography

1. Davis, N., and Telford, R. T., "Manual Magnetic-Flux Gas-Shielded Arc Welding of Mild Steel," The Welding Journal, 36(5): 475-480 (1957).
2. Nelson, L., "New Continuous-Feed Process Cuts Welding Costs," Iron Age, 127-129 (March 7, 1957).

Fig. 19 Vertical repair welding in a rock-crusher casting using $^{3}/_{64}$-in. diam wire

INERT-GAS-SHIELDED ARC WELDING OF SILICON AND ALUMINUM BRONZE

Detailed information is provided pertinent to proper joint design, welding procedures, shielding gas, operational techniques and mechanical strength of welded joints

BY PAUL L. HEMMES

ABSTRACT. The purpose of this paper is to provide detailed information pertinent to the welding of silicon bronze and aluminum bronze by the inert-gas-shielded metal-arc and the inert-gas-shielded tungsten-arc welding processes.

For many years the oxyacetylene, carbon-arc or metal-arc processes provided the only successful methods of welding these alloys. In most applications, however, the inert-gas-shielded arc-welding processes, when employed with proper techniques and procedures, are more efficient for welding both silicon and aluminum bronze than any of the above-mentioned processes.

The inert-gas-shielded arc-welding processes can also be employed successfully for welding these alloys to some other metals.

Complete details pertinent to proper joint design, welding procedures, shielding gas, operational techniques and mechanical strength of welded joints are included herein.

Procedure details and operational techniques relative to welding these alloys to some other metals are also discussed.

Introduction

Silicon bronze and aluminum bronze both offer advantages to the modern designer when it is desirable to incorporate a high-strength, corrosion-resistant material in the design of a welded structure.

Until recently, many designers and fabricators have been reluctant to employ copper-base alloys because they considered them too difficult to weld.

Welding processes that are now considered obsolete for welding these alloys required the use of flux in one form or another to produce welds capable of meeting code requirements. In addition, it was often necessary or desirable to preheat, and, moreover, weld deposition rates were low as compared to the modern gas-shielded arc processes.

Newer and better equipment to meet the needs of advances in industry, including the requirements for high-strength, corrosion-resistant materials for AEC uses, has stimulated interest in a more extended use of copper-base alloys. In addition, the constant search for more efficient methods of fabrication has led to the extensive use of the inert-gas-shielded arc-welding processes in most applications where these alloys are used.

Paul L. Hemmes is welding engineer associated with the Research Department of Revere Copper and Brass, Inc.

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Due to present-day demands, many shops formerly concerned primarily with the welding of ferrous materials now find it necessary to incorporate one or more of the copper-base alloys in the design of a welded structure.

The inert-gas-shielded arc-welding processes are very well suited to welding either silicon bronze or aluminum bronze because they do not require the use of flux. Usually they do not require preheat and weld deposition rates are high. They are also well suited to automatic or semiautomatic operation.

The methods, techniques and procedures reported herein are the results of several years of study in the development of correct procedures for welding these alloys by the inert-gas-shielded arc-welding processes.

Procedure

Equipment and Materials

Equipment. All of the welds produced in this series of tests were made employing commercially available equipment that was in no way modified for laboratory work.

The inert-gas-shielded tungsten-arc welds made in the silicon-bronze material employed in these tests and all of the inert-gas-shielded metal-arc welds were made employing a three-phase direct-current rectifier-type 60-cycle power source of 600-amp capacity.

All inert-gas-shielded tungsten-arc welds made in the aluminum-bronze material employed high-frequency stabilized alternating current with automatic gas and water controls.

The inert-gas-shielded tungsten-arc welds were made employing standard 250 and 400 amp capacity electrode holders or torches. A $\frac{3}{32}$-in., 2% thoriated-tungsten electrode tapered to an approximate 60-deg included angle was employed for all tungsten-arc welds.

The inert-gas-shielded metal-arc welds were made employing standard consumable-electrode equipment.

Recording volt and ampere meters were used to measure and record welding currents and arc voltages.

Argon was used exclusively as a shielding gas. Flow rates were measured employing standard-type flow

Table 1—Chemical and Mechanical Requirements of Aluminum-Bronze and Silicon-Bronze Base Metals as Given in ASTM and Military Specifications

Element	*ASTM 169, Alloy D, aluminum bronze*	*ASTM 96, Alloy A, silicon bronze*	*MIL-A-15639A, Composition 5, aluminum bronze*	*MIL-C-17516, Composition 1, silicon bronze*
Copper	88.0-92.5	94.8 min	88.0-92.5	Remainder
Aluminum	6.0-8.0		6.0-8.0	
Iron	1.5-3.5	1.6 max	3.5 max	2.5 max
Nickel		0.6 max		1.0 max
Silicon		2.8-3.8		1.0-3.6
Manganese		1.5 max	1.0 max	
Tin				0.7 max
Zinc		1.5 max		1.5 max
Phosphorus		0.05 max		0.8 max
Other	0.50 max	0.50 max	0.50 max	0.50 max
Minimum tensile strength, psi	70,000	50,000	70,000	50,000

NOTE: Above specifications same as UNF 23, Section 8, ASME Boiler and Pressure Vessel Code.

Table 2—Typical Chemical Analyses of Aluminum-Bronze and Silicon-Bronze Filler Metals Employed in This Series of Tests

Element	*Element in Cu-Al Wire, %*	*Element in Cu-Si Wire, %*
Copper	89.70	95.92
Silicon	0.05*	3.08
Manganese	0.004*	0.92
Iron	0.05*	0.04*
Lead	0.004*	0.002*
Tin	0.004*	0.003*
Nickel	0.007*	0.003*
Aluminum	10.18	0.000

* Spectrographic determination.

meters calibrated in cubic feet/hour.

Materials. Base materials employed in this investigation were in thicknesses of $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{1}{2}$ in. The composition and mechanical properties of these materials are shown in Table 1.

All inert-gas-shielded metal-arc welds were made employing $\frac{1}{16}$-in. diam filler wire. Composition of these filler metals conforms to Tentative Specifications for Copper and Copper-Alloy Welding Electrodes AWS A5.6-53—ASTM B225-57T Classification ECuSi and ECuAl-A2.

All inert-gas-shielded tungsten-arc welds were made employing rods of sufficient diameter to produce a layer or bead depth of approximately $\frac{1}{8}$ in. by using about 1 in. of rod per inch of weld. Composition of these filler metals conforms to Tentative Specifications for Copper and Copper-Alloy Rods AWS A5.7-52—ASTM B259-57T Classification RCuSi-A and RCuAl-A2. The chemical analyses of the actual filler metals used are shown in Table 2.

Welding. A total of 15 test plates was produced to compile the information contained herein. Welds made by the inert-gas-shielded metal-arc welding process in $\frac{1}{4}$-in. thick material were produced employing a $\frac{1}{4}$- x 1-in. backing strip of the base metal. Dissimilar-metal welds were also produced employing backing strips. All other welds were produced employing removable grooved copper backing bars.

Welding—Aluminum Bronze. There are no particular difficulties encountered in the welding of aluminum bronze by the inert-gas-shielded metal-arc process if one adheres to good welding practice. However, this alloy, during mill processing, does develop surface oxides which must be mechanically removed before welding or they will interfere with the attainment of sound welds.

The characteristics of the inert-gas-shielded metal-arc process make it well suited to welding aluminum bronze either manually or by semiautomatic or auto-

Table 3—Summary of Joint Design Used to Produce Test Welds

Weld identification	*Base metal*	*Thickness, in.*	*Joint design*	*Root face, in.*	*Root space, in.*	*Backing*
GSMA-105*	Aluminum bronze	$\frac{1}{2}$	60-deg included angle	None	$\frac{1}{8}$	Grooved copper
GSMA-106	Aluminum bronze	$\frac{3}{8}$	60-deg included angle	None	$\frac{1}{8}$	Grooved copper
GSMA-107	Aluminum bronze	$\frac{1}{4}$	Square butt	$\frac{1}{8}$	None	$\frac{1}{4}$- × 1- Al-bronze strip
GSMA-108	Silicon bronze	$\frac{1}{2}$	60-deg included angle	None	$\frac{1}{8}$	Grooved copper
GSMA-109	Silicon bronze	$\frac{3}{8}$	60-deg included angle	None	$\frac{1}{8}$	Grooved copper
GSMA-110†	Silicon bronze	$\frac{1}{4}$	Square butt	$\frac{1}{4}$	None	None
GSMA-111	Silicon bronze	$\frac{1}{4}$	Square butt	$\frac{1}{8}$	None	$\frac{1}{4}$- × 1- Si-bronze strip
GSMA-112	Al bronze to steel	$\frac{3}{8}$	60-deg included angle	None	$\frac{3}{8}$	$\frac{1}{4}$- × 1- Si-bronze strip
GSMA-113	Si bronze to steel	$\frac{3}{8}$	60-deg included angle	None	$\frac{1}{8}$	$\frac{1}{4}$- × 1- Si-bronze strip
GSMA-114	Al bronze to Si bronze	$\frac{3}{8}$	60-deg included angle	None	$\frac{1}{8}$	Grooved copper
GSTA-88‡	Silicon bronze	$\frac{1}{2}$	60-deg included angle	None	$\frac{1}{8}$	Grooved copper
GSTA-89	Silicon bronze	$\frac{3}{8}$	60-deg included angle	None	$\frac{1}{8}$	Grooved copper
GSTA-90	Silicon bronze	$\frac{1}{4}$	Square butt	$\frac{1}{8}$	$\frac{1}{8}$	Grooved copper
GSTA-91	Aluminum bronze	$\frac{3}{8}$	60-deg included angle	None	$\frac{1}{8}$	Grooved copper
GSTA-92	Aluminum bronze	$\frac{1}{4}$	Square butt	$\frac{1}{8}$	$\frac{1}{8}$	Grooved copper

* The prefix GSMA indicates the use of the inert-gas-shielded metal-arc process.
† Travel carriage was used to control welding speed. Weld was made from both sides of plate with no edge preparation.
‡ The prefix GSTA indicates the use of the inert-gas-shielded tungsten-arc process.

matic methods. When proper welding current, arc voltage and gas-flow rates are used, a spray-type weld-metal transfer results. The resultant weld, when wire brushed, has a golden appearance with a uniform contour. Good penetration is easily obtained and sound welds are not difficult to achieve.

A summary of the joint geometry and welding-procedure details used to produce welds in aluminum bronze by the above process are shown in Tables 3 and 4, respectively. Mechanical-test results are shown in Table 5.

For welding aluminum bronze by the inert-gas-shielded tungsten-arc process, the characteristics of alternating current make it the most suitable type of power source. Alternating current breaks up the tenacious oxides which form as a result of the application of

Table 4—Summary of Procedure Details Used to Produce the Test Welds

Weld identification	*Base metal*	*Thickness, in.*	*Welding current, amp*	*Arc, v*	*Shielding gas, cfh*	*No. of passes*	*Filler metal: Diam, in.*	*Filler metal: Pass*
GSMA-105*	Aluminum bronze	1/4	DCSRP 280-290	29-30	Argon-30	3	1/16	All
GSMA-106	Aluminum bronze	3/8	DCSRP 280-290	29-30	Argon-30	2	1/16	All
GSMA-107	Aluminum bronze	1/2	DCSRP 280-290	29-30	Argon-30	1	1/16	All
GSMA-108	Silicon bronze	1/4	DCSRP 260-270	28-29	Argon-30	3	1/16	All
GSMA-109	Silicon bronze	3/8	DCSRP 260-270	28-29	Argon-30	2	1/16	All
GSMA-110†	Silicon bronze	1/2	DCSRP 310-320	30-31	Argon-30	2	1/16	All
GSMA-111	Silicon bronze	1/2	DCSRP 260-270	28-29	Argon-30	1	1/16	All
GSMA-112	Al bronze to steel	3/8	DCSRP 270-280	26-27	Argon-30	6	1/16	All
GSMA-113	Si bronze to steel	3/8	DCSRP 260-270	28-29	Argon-30	6	1/16	All
GSMA-114	Si bronze to Al bronze	3/8	DCSRP 260-270	28-29	Argon-30	3	1/16	All
GSTA-88‡	Silicon bronze	1/4	DCSRP 180-330		Argon-30	6	See text	
GSTA-89	Silicon bronze	3/8	DCSRP 180-290		Argon-30	4	See text	
GSTA-90	Silicon bronze	1/2	DCSRP 200		Argon-30	1	3/32	
GSTA-91	Aluminum bronze	3/8	AC 210-330		Argon-30	4	3/32	All
GSTA-92	Aluminum bronze	1/2	AC 210		Argon-30	1	3/32	All

* The prefix GSMA indicates the use of the inert-gas-shielded metal-arc process.
† Travel carriage used to control welding speed. Weld made from both sides of plate with no edge preparation.
‡ The prefix GSTA indicates the use of the inert-gas-shielded tungsten-arc process.

Table 5—Summary of Mechanical-Test Results

Weld identification	*Base metal*	*Thickness, in.*	*Ultimate tensile strength, psi*	*Occurrence of failure*	*Face bend*	*Root bend*
GSMA-105*	Aluminum bronze	1/4	74,400	Base	OK	OK
			71,500	Weld	OK	OK
GSMA-106	Aluminum bronze	3/8	72,100	Weld	OK	OK
			71,600	Weld	OK	OK
GSMA-107	Aluminum bronze	1/2	70,800	Weld	OK	OK
			70,500	Weld	OK	OK
GSMA-108	Silicon bronze	1/4	57,200	Weld	OK	OK
			55,800	Weld	OK	OK
GSMA-109	Silicon bronze	3/8	57,300	Base	OK	OK
			57,700	Base	OK	OK
GSMA-110†	Silicon bronze	1/2	59,000	Base	OK	OK
			58,300	Base	OK	OK
GSMA-111	Silicon bronze	1/2	53,500	Base	OK	OK
			55,500	Base	OK	OK
GSMA-112	Al bronze to steel	3/8	62,500	Steel	OK	OK
			62,300	Weld	OK	OK
GSMA-113	Si bronze to steel	3/8	57,800	Steel	OK	OK
			57,600	Weld	OK	OK
GSMA-114	Al bronze to Si bronze	3/8	58,800	Weld	Failed	Failed
			59,800	Weld	Failed	Failed
GSTA-88‡	Silicon bronze	1/4	55,700	Base	OK	OK
			55,100	Weld	OK	OK
GSTA-89	Silicon bronze	3/8	53,100	Weld	OK	OK
			54,000	Weld	OK	OK
GSTA-90	Silicon bronze	1/2	58,700	Base	OK	OK
			52,100	Weld	OK	OK
GSTA-91	Aluminum bronze	3/8	74,400	Base	OK	OK
			71,700	Weld	OK	OK
GSTA-92	Aluminum bronze	1/2	71,500	Weld	OK	OK
			74,800	Base	OK	OK

* Prefix GSMA and GSTA indicate welding process used. See Tables 3 and 4 for complete explanation.
† Travel carriage was used to control welding speed.
‡ Weld made from both sides with no edge preparation.

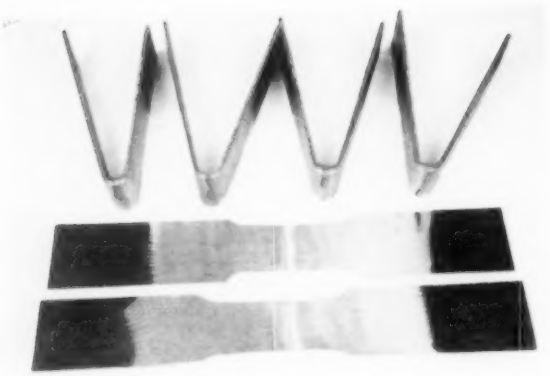


Fig. 1 Bend and tensile specimens of weld GSTA 92. Tensile specimens failed at 71,500 and 74,800 psi, see Table 5. Base metal was aluminum bronze. One failure occurred in base metal adjacent to the weld. X ½

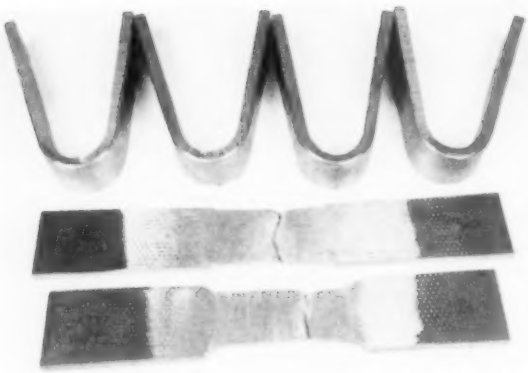


Fig. 3 Bend and tensile specimens of weld GSMA 106. Tensile specimens failed at 72,100 and 71,600 psi. Failures occurred in weld. Base metal was aluminum bronze. See Table 5. X ½

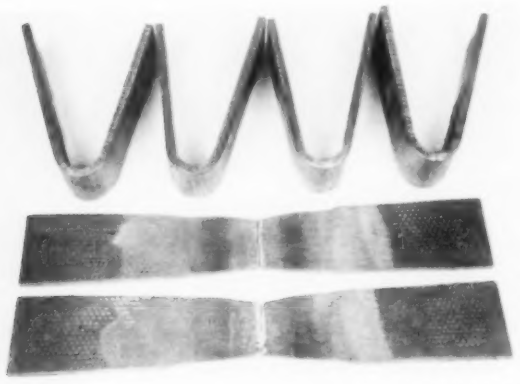


Fig. 2 Bend and tensile specimens of weld GSMA 110. Tensile specimens failed at 57,000 and 59,000 psi. Failures occurred in base metal adjacent to the weld. An automatic travel carriage was used to produce this weld. Base metal was silicon bronze. See Table 5. X ½

Fig. 4 Bend and tensile specimens of weld GSMA 112. Tensile specimens failed at 62,500 and 62,300 psi. One failure occurred in steel, the other failure occurred at interface between weld and steel. Base metals were aluminum bronze and steel. X ½

heat during welding. If material of a thickness requiring only one weld pass is properly cleaned prior to welding, these oxides present no serious problem. If reasonable care is used to prevent overheating during multipass welding, interpass wire brushing is sufficient for cleaning.

Tables 3 and 4, respectively, show summaries of the joint geometry and welding-procedure details used to produce welds in aluminum bronze by the inert-gas-shielded tungsten-arc process. Mechanical-test results are shown in Table 5.

Welding Silicon Bronze. Silicon bronze is not a difficult metal to weld by the inert-gas-shielded metal-arc welding process. However, experience has shown that, due to its hot-short characteristics, the best results are obtained when travel speeds exceed 8 ipm and interpass temperatures are held below 225° F. Preheat should not be used. Any mill scale present on silicon bronze should be removed before welding. Welds made with this process have good appearance and consistently high quality when proper procedures are employed.

Tables 3 and 4, respectively, show the summaries of joint geometry and procedure details used to produce welds in silicon bronze by this process. Mechanical-test results are shown in Table 5.

Silicon bronze can be readily welded by the inert-gas-shielded tungsten-arc welding process with or without the use of backing bars or backing strips. Direct-current straight polarity is best suited for this operation. High travel speeds and interpass temperatures below 225° F are also necessary with the use of this process.

Tables 3 and 4, respectively, show summaries of joint geometry and procedure details used to produce welds in silicon bronze with this process employing removable copper backing bars. Mechanical-test results are shown in Table 5.

To illustrate the manner in which silicon bronze can be welded by the inert-gas-shielded tungsten-arc weld-

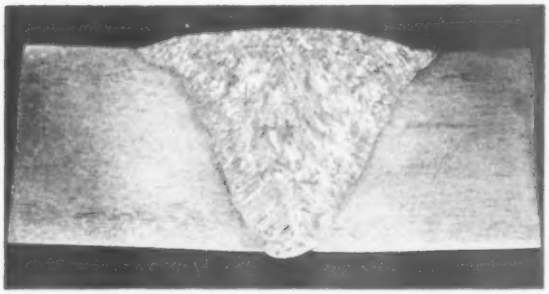


Fig. 5 Photomacrograph of a cross section of weld GSMA 105, produced in ½-in. aluminum-bronze plate by the manual inert-gas-shielded metal-arc process. This weld was completed in three passes. X 2. (Reduced by ½ upon reproduction)

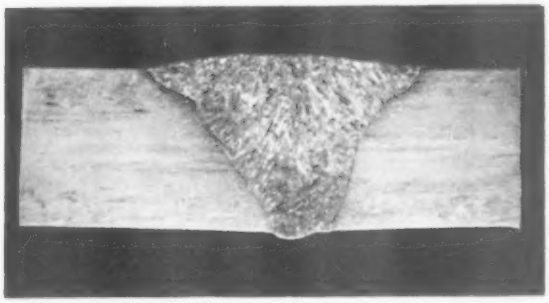


Fig. 6 Photomacrograph of a cross section of weld GSMA 106, produced in ½-in. aluminum-bronze plate employing the manual inert-gas-shielded metal-arc process. This weld was completed in two passes. X 4½. (Reduced by ½ upon reproduction)

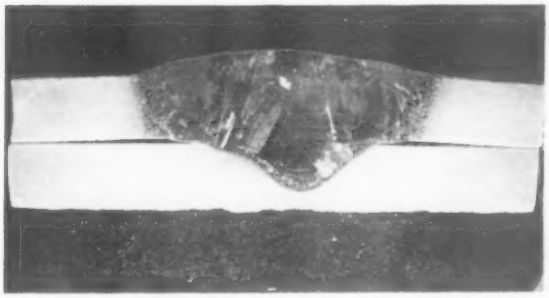


Fig. 7 Photomacrograph of a cross section of weld GSMA 107, produced in ½-in. aluminum-bronze plate by the manual inert-gas-shielded metal-arc process. A square butt joint and a 1- x ¼-in. backing strip of aluminum bronze was employed. X 5. (Reduced by ½ upon reproduction)

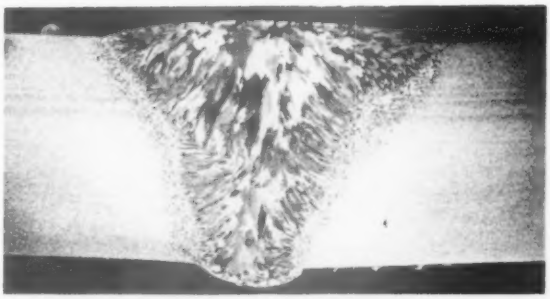


Fig. 8 Photomacrograph of a cross section of weld GSMA 108, produced in ½-in. silicon-bronze plate by the manual inert-gas-shielded metal-arc process. This weld was completed in three passes. X 2. (Reduced by ½ upon reproduction)

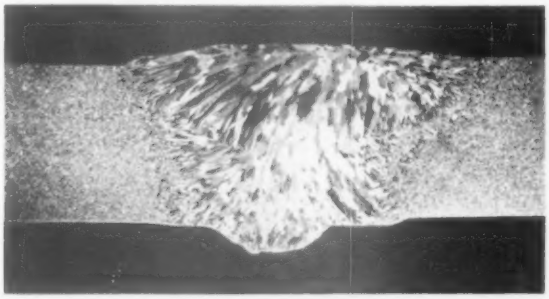


Fig. 9 Photomacrograph of a cross section of weld GSMA 109, produced in ½-in. silicon-bronze plate by the manual inert-gas-shielded metal-arc process. The weld was completed in two passes. X 4½. (Reduced by ½ upon reproduction)

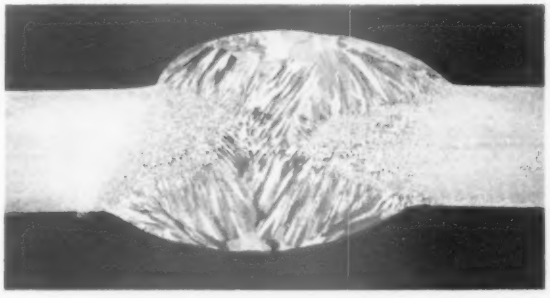


Fig. 10 Photomacrograph of a cross section of weld GSMA 110 produced in ½-in. silicon-bronze plate by the inert-gas-shielded metal-arc process. It was completed in two passes employing a travel carriage for automatic control. One pass was made on each side employing a square butt joint. Some slight misalignment resulted when the second pass was made on the reverse side. Note completely satisfactory penetration. X 5. (Reduced by ½ upon reproduction)

ing process without the use of weld backing of any kind, the following specialized technique can often be used by skilled operators when it is impossible to provide backing.

Figure 14 shows a cross section of Weld GSTA 88 made in ½-in. silicon-bronze plate using this specialized technique.

Direct-current straight polarity was used with argon at a flow rate of 30 cfh. A 60-deg included groove angle was used with a ⅛-in. root opening. After tacking to maintain alignment, the first pass was made using a 5/32-in. diam rod at 185–190 amp and travel speed of 12 ipm. The arc was held directly on the rod simultaneously melting the rod and fusing it to the root. In this manner, an experienced operator can consistently obtain nearly 100% penetration and at the same time obtain adequate reinforcement on the reverse side of the

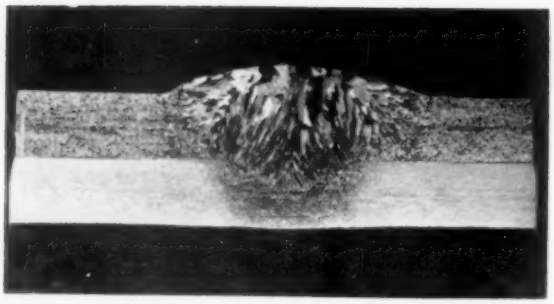


Fig. 11 Photomacrograph of a cross section of weld GSMA 111 produced in $\frac{1}{8}$-in. silicon-bronze plate by the manual inert-gas-shielded metal-arc process. A square butt was employed with a 1- x $\frac{1}{8}$-in. back-up strip. X 5. (Reduced by $\frac{1}{2}$ upon reproduction)

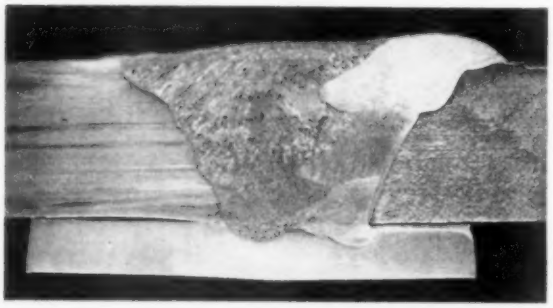


Fig. 12 Photomacrograph of a cross section of weld GSMA 112 produced by the manal inert-gas-shielded metal-arc process. It was completed in six passes. In this case, aluminum bronze is joined to steel employing a 10% aluminum-bronze filler wire. A 60-deg included-angle groove was employed with a $\frac{3}{8}$-in. root opening and a back-up strip of aluminum bronze. Left side is aluminum bronze—right side is steel. X 2. (Reduced by $\frac{1}{2}$ upon reproduction)

Fig. 13 Photomacrograph of a cross section of weld GSMA 113 produced by the manual inert-gas-shielded metal-arc process. It was completed in six passes. In this case, silicon bronze is joined to steel employing a 10% aluminum-bronze filler wire. A 60-deg included-angle groove was used with an aluminum-bronze back-up strip. Left side is silicon bronze, right side is steel. X $3\frac{1}{2}$. (Reduced by $\frac{1}{2}$ upon reproduction)

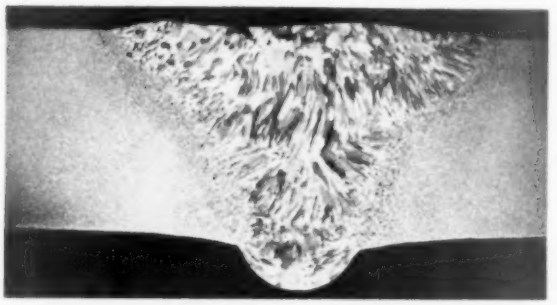


Fig. 14 Photomacrograph of a cross section of weld GSTA 88 produced in $\frac{1}{2}$-in. silicon-bronze plate by the manual inert-gas-shielded tungsten-arc process. The weld was completed in six passes. Filler rod employed for each pass was of a diameter to produce a layer of approximately $\frac{1}{8}$-in. depth when rod was used at the rate of one inch per inch of weld. A 60-deg included-angle groove was employed in this joint with no back-up support of any kind. Straight polarity direct current was used. X 2. (Reduced by $\frac{1}{2}$ upon reproduction)

weld without danger of burning through or the formation of icicles. The second pass was made employing a $\frac{5}{32}$-in. diam rod at 225–230 amp. The second pass required a travel speed of about 14 ipm to avoid burn-through. The third pass was made employing a $\frac{3}{16}$-in. diam rod at 275 amp and travel speed of 12 ipm. The fourth pass was made employing a $\frac{1}{4}$-in. rod at 315 amp and travel speed of $10\frac{1}{2}$ ipm. The fifth pass was made employing a $\frac{5}{16}$-in. diam rod at 365 amp at 9-ipm travel speed. Final pass was made employing a $\frac{3}{8}$-in. diam rod at 390 amp and 9-ipm travel speed.

The filler-rod diameters employed are such that the use of 1 in. of rod per inch of pass automatically provides a pass depth of approximately $\frac{1}{8}$ in. Selection of rod in this manner makes it unnecessary for the operator either to feed or drag the filler rod. This method of adding filler metal makes layer depth consistent, resulting in a weld having an excellent appearance.

The joint geometry employed for the welds in this series is shown in Table 3.

A summary of all of the welding-procedure details employed in the production of welds produced for this investigation is shown in Table 4.

Welding Dissimilar Metals. Sometimes for purposes of strength, corrosion resistance or economy, the modern designer may wish to join a copper-base alloy to steel. Numerous tests in the past few years have shown that both silicon bronze and aluminum bronze may be satisfactorily welded to steel by the inert-gas-shielded metal-arc process employing a 10% aluminum-bronze filler metal conforming to AWS Classification ECuAl-A2.

For the joining of either of these alloys to steel, an overlay of aluminum bronze is required. In joining aluminum bronze to steel the overlay is required only on the steel. Satisfactory welds between silicon bronze and steel have been produced by employing an overlay either on the silicon bronze or the steel.

In either case, root openings of at least $\frac{3}{8}$ in. are desirable, since for purposes of economy it is desirable to provide a joint design that will permit the application of the overlay in sequence with deposition of the joining

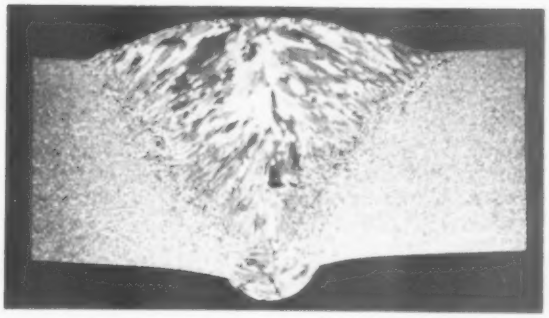


Fig. 15 Photomacrograph of a cross section of weld GSTA 89 produced in $\frac{3}{8}$-in. silicon-bronze plate by the manual inert-gas-shielded tungsten-arc process. Four passes were required to complete the weld. A 60-deg included-angle groove was used. Straight polarity direct current was used. X $4\frac{1}{2}$. (Reduced by $\frac{1}{3}$ upon reproduction)

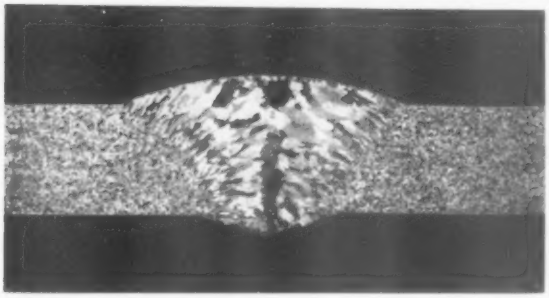


Fig. 16 A photomicrograph of a cross section of weld GSTA 90 produced in $\frac{1}{8}$-in. silicon-bronze plate by the manual inert-gas-shielded tungsten-arc process. The weld was completed in one pass. A square butt joint was employed. X $4\frac{1}{2}$. (Reduced by $\frac{1}{3}$ upon reproduction)

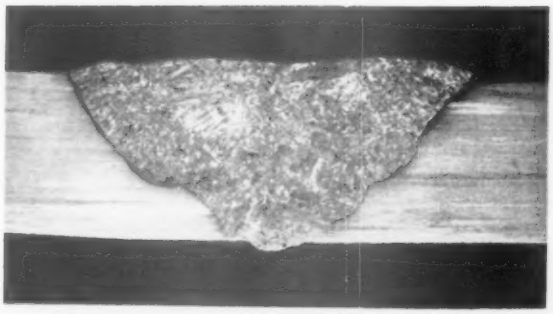


Fig. 17 A photomacrograph of a cross section of weld GSTA 19 produced in $\frac{3}{8}$-in. aluminum-bronze plate by the manual inert-gas-shielded tungsten-arc process employing alternating current. This weld was made in four passes. A 75-deg included-angle groove was employed. X $4\frac{1}{2}$. (Reduced by $\frac{1}{3}$ upon reproduction)

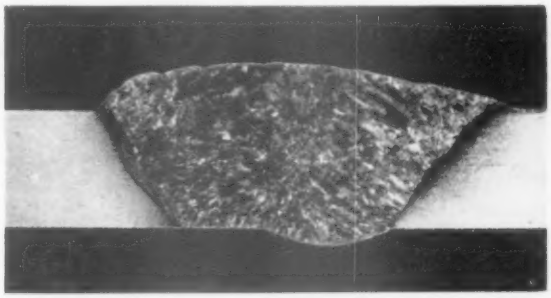


Fig. 18 Photomacrograph of a cross section of weld GSTA 92 produced in $\frac{1}{8}$-in. aluminum-bronze plate by the manual inert-gas-shielded tungsten-arc process using alternating current. This weld was completed in one pass. A slight groove was ground on the butting edges. X $4\frac{1}{2}$. (Reduced by $\frac{1}{3}$ upon reproduction)

passes. Furthermore, large root openings insure accessibility to the root so that full penetration can be obtained with both the overlay and joining passes.

In both cases, steel conforming to the Unfired Pressure Vessel Code, Specification SA285-B, P No. 1 material was employed to produce the following test welds.

Welding Aluminum Bronze to Steel. The attainment of satisfactory welds between aluminum bronze and steel is not difficult with the use of the inert-gas-shielded metal-arc process. Quality welds, however, demand penetration into the steel side of the joint. Inadequate penetration into the steel results in a braze weld. This will produce satisfactory tensile strength but ductility will be poor. The results of several tests have proved that when adequate penetration into the steel has not been obtained, longitudinal bend specimens will inevitably fail at the filler metal-steel interface.

Figure 12 shows a macrograph of a weld between aluminum bronze and steel.

The joint geometry, procedure details and results of mechanical testing are shown in Tables 3, 4 and 5, respectively. In this case, longitudinal bend specimens were made.

Welding—Silicon Bronze to Steel. The results of numerous initial tests using the inert-gas-shielded metal-arc process employing various techniques and filler metals revealed that AWS Type ECuAl-A2 filler metal was best suited for joining silicon bronze to steel. These tests also revealed that hot-short cracking along the fusion line on the silicon-bronze side could be produced at will. They also revealed the necessity of two things. First, it was necessary to obtain good penetration into the steel to prevent braze welding of the aluminum bronze to steel; secondly, it was found that excessive dilution of silicon bronze in the filler metal usually resulted in transverse cracking along the silicon-bronze side of the joint when longitudinal bend tests were made.

It was therefore concluded that an overlay of aluminum bronze on the silicon bronze would provide an insulating or buffer layer which would minimize dilution and, at the same time, if a large enough root opening were employed, it would permit accessibility to the steel side for the required penetration. Other later tests bore out this conclusion.

Figure 13, Weld GSMA 113, shows a photomacro-

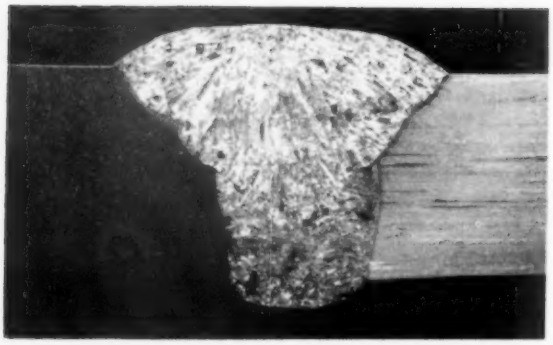


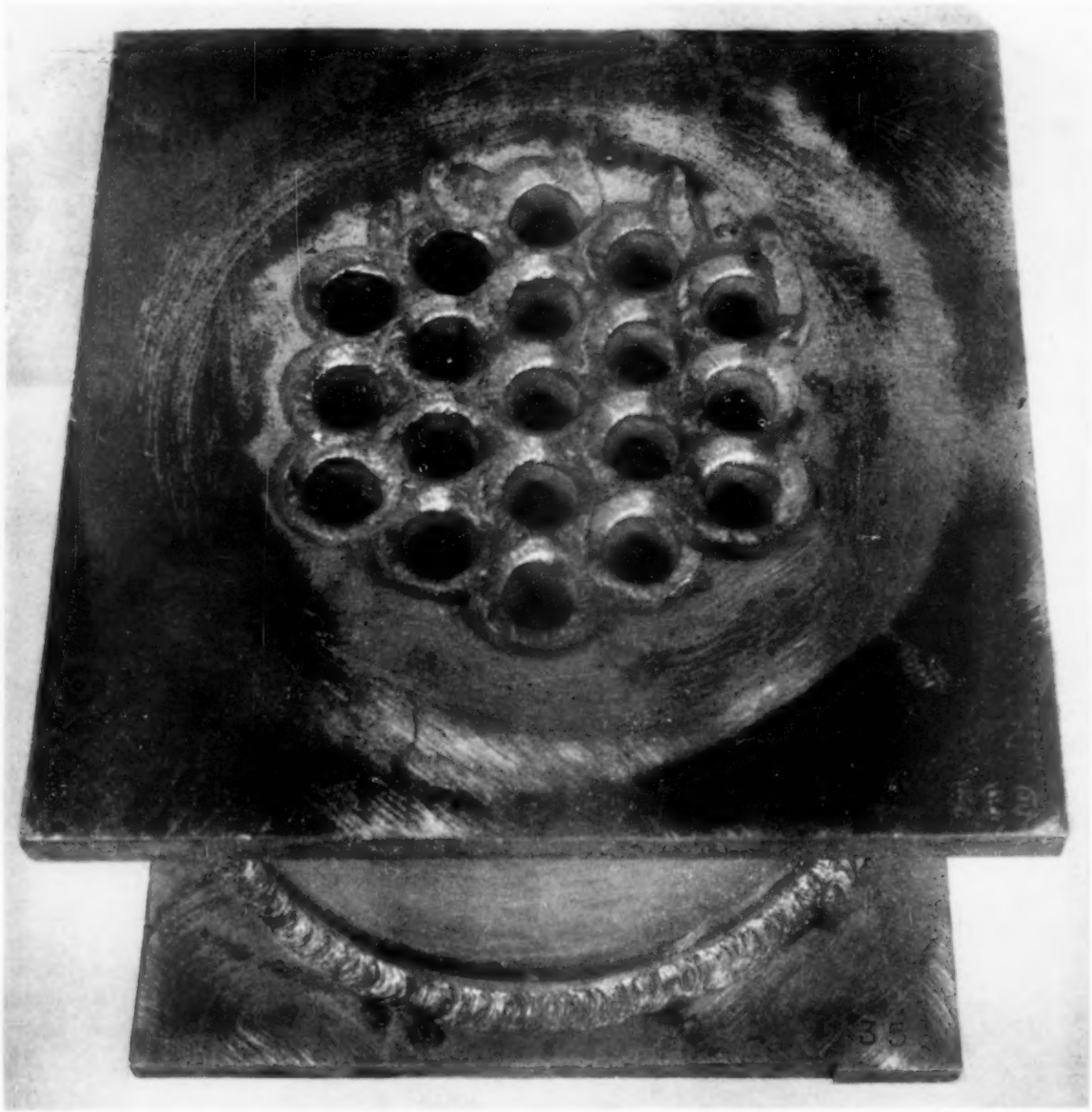
Fig. 19 Photomacrograph of a cross section of weld GSMA 114 between $\frac{3}{8}$-in. aluminum-bronze plate and silicon-bronze plate. Aluminum-bronze filler wire was used. Left side is silicon bronze, right side is aluminum bronze. X $4\frac{1}{2}$. (Reduced by $\frac{1}{3}$ upon reproduction)

graph of a weld between silicon bronze and steel. The joint geometry, procedure details and results of mechanical testing are shown in Tables 3, 4 and 5, respectively.

A subsequent restrained-weld test plate was made in $\frac{1}{2}$- x 18- x 18-in. steel plate having a 5- x 6-in. opening, into which was welded a $\frac{3}{8}$-in. plate of silicon bronze to ascertain further if this procedure would be satisfactory.

After visual examination, which showed no cracking of the weld, two reduced-section tensile specimens were removed from the plate and mechanically tested. These test specimens gave tensile strengths of 54,000 and 55,700 psi, respectively.

Fig. 20 Photomacrograph of a small experimental heat-exchanger unit. Tube sheet is $\frac{1}{2}$-in. silicon-bronze plate; tubes are $\frac{3}{4}$- x 0.049-in. Admiralty metal. X $\frac{1}{4}$



Failure was initiated in the weld metal in one specimen with the fracture extending into the silicon-bronze base metal. In the other specimen, failure occurred entirely in the base metal.

A photograph of the restrained weld test plate is shown in Fig. 22.

Mechanical Testing. After welding, each test plate was cut to provide two reduced-section tensile, two face-bend, two root-bend specimens, and one specimen for metallographic study as shown in Fig. QN-13.1 (a) for welds in similar materials, and Fig. QN-13.1 (c) for dissimilar-metal joints as shown in Section IX of the ASME Unfired Pressure Vessel Code.

Mechanical tests were conducted on a 100,000-lb capacity testing machine in conjunction with a guided-bend testing jig.

The guided-bend tests were made employing a roll diameter equal to four times the thickness of the specimen being tested as prescribed by the ASME procedure for weld qualification.

A summary of mechanical-test results is shown in Table 5.

Some typical examples of bend and tensile specimens were selected at random from this group and are shown in Figs. I through L respectively.

Metallographic Examination. The metallographic section from each test plate was examined macrographically. All sections showed complete absence of porosity or other defects.

Figures 5 through 18 are photomacrographs of these cross sections as indicated in the captions.

The etchant employed in all cases was a 1:1 chromic acid solution.

Other Dissimilar-Metal Combinations—Silicon Bronze to Aluminum Bronze. For experimental purposes only, a test weld between aluminum bronze and silicon bronze was made with the inert-gas-shielded tungsten-arc process employing ECuAl-A2 filler metal. A cross section of this weld is shown in Fig. 19. The two tensile specimens developed ultimate tensile strengths of 58,800 and 59,800 psi. Transverse-bend specimens were made and testing resulted in failure in all cases. Longitudinal-bend specimens as prescribed in QN-13(c) of the ASME Unfired Pressure Vessel Code should have been used.

Another example of a dissimilar-metal weld combination is shown in Fig. 20. This is a photograph of a small experimental heat-exchanger unit that was made in the laboratory. The tubes in this test unit were $\frac{3}{4}$-in. OD x 0.049-in. wall Admiralty metal. The tube sheet was $\frac{1}{2}$-in. silicon bronze. The welds between the tubes and tube sheet were made by the manual inert-gas-shielded tungsten-arc process. Direct-current straight polarity was used at 170 amp. Argon at 30 cfh was used for shielding. Welding time for each tube varied from 11 to 16 sec.

It was found that production of satisfactory welds of this type required a very short arc length and extremely fast rate of travel to avoid excessive zinc volatilization which always resulted in porous welds.

Later, automatic equipment was developed which produces circular welds of this type in many combinations of various alloys.

A section of this experimental unit, after hydrostatic testing to 1800 psi, is shown in Fig. 21.

Discussion

The extended use of the inert-gas-shielded arc-welding processes in the past few years has greatly simplified the welding of both silicon bronze and aluminum bronze. For the most part, techniques are simple.

The consistent attainment of high-strength and highly ductile welds with the use of these processes is evidenced by an examination of Table 5. In all cases in this series of test welds, minimum tensile requirements were exceeded. Bend tests were satisfactory in all cases.

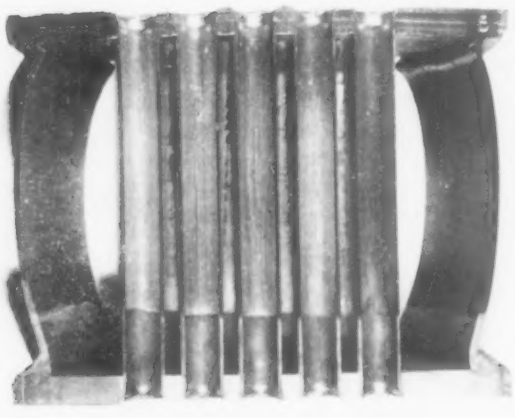


Fig. 21 Photograph of a cross section of the experimental heat-exchanger unit shown in Fig. 20 after hydrostatic testing to 1800 psi. X $\frac{1}{2}$ Approx.

Fig. 22 View of a restrained-weld test plate, silicon bronze to steel, after completion of the weld. X $\frac{1}{8}$

No specialized techniques are required for welding of aluminum bronze by these processes. However, because of its hot-short characteristics, the welding of silicon bronze does require a knowledge of certain precautions which are necessary to achieve quality welds. As a result, these precautions are prescribed as follows:

1. Preheat should not be used.

2. Interpass temperatures should not exceed 225° F. The control of interpass temperature is usually provided automatically in large weldments. For small subassemblies or for components where heat buildup is likely to occur, the necessary interpass cooling must be provided.

3. High welding speeds and a weld bead or pass consistent with these high welding speeds should be employed in order to avoid a high base-metal temperature adjacent to the weld. These travel speeds should exceed 8 ipm for best results.

The proper rate of progression is readily achieved with the use of automatic or semiautomatic equipment. A weld produced in such a manner is shown in Fig. 10. Joint geometry, procedure details and mechanical-test results are shown in Tables 3, 4 and 5.

An adequate rate of progression is not difficult to maintain with the manual inert-gas-shielded metal-arc process. In most cases, however, operators inexperienced in the welding of silicon bronze by the manual inert gas-shielded tungsten-arc process often find the high travel speeds difficult to achieve, since somewhat higher than normal welding currents are required to produce the desired results. Proficiency, however, is soon gained with practice.

The demand for welding of certain dissimilar-metal combinations appears to be increasing. When a designer is faced with such a problem he often finds that there are certain disadvantages to welding some combinations of dissimilar metals in that in many cases it is impossible to find a filler metal that is metallurgically suited to the base materials involved. Consequently, it is often necessary to develop specialized procedures and techniques to suit both the process and filler metals that are available for use.

The use of an insulating or buffer layer of weld metal to minimize dilution of some undesirable element contained in one of the base metals is not an uncommon practice. This often provides a very satisfactory method of joining dissimilar metals. Usually, satisfactory tensile strengths are readily achieved. However, when base metals with appreciable differences in ductility and strength are joined in this manner, ductility requirements are sometimes difficult to meet. Conventional transverse-bend specimens nearly always fail on mechanical testing. This is plainly evidenced by the failure of the transverse-bend specimens of Weld GSMA 114, aluminum bronze to silicon bronze. However, the use of longitudinal-bend specimens as prescribed in Fig. QN-13.1 (c) of the ASME Unfired Pressure Vessel Code permits a method of testing such welds wherein satisfactory ductility requirments can be more readily achieved.

When specialized techniques and procedures are required for welding, even skilled operators require additional training to produce consistently satisfactory welds. Furthermore, when such techniques require an overlay of weld metal, its application can be a disadvantage if it is necessary to apply the overlay prior to joining of the base metals. This often necessitates an additional operation of grinding or machining of the overlay to provide a proper fit. Furthermore, since additional filler metal is required to produce that overlay, and since in the described methods large root spacing is required, a greater number of weld passes is thus required to complete the weld. This results in a more than normal consumption of filler metal and also an increase in welding time. Consequently, for purposes of economy, the designer wishing to employ such methods of joining should attempt, if at all possible, to provide a joint design and shape of workpiece that will readily permit the application of the overlay or buffer layer in sequence with the joining passes.

Conclusions

1. Quality welds in both silicon bronze and aluminum bronze can be consistently produced with the use of the inert-gas-shielded arc-welding processes employing commercially available filler metals.

2. Operators can be trained in the proper techniques of welding these alloys in a relatively short time. When properly trained operators employ these processes with satisfactory procedures that are developed to suit the intended application, they provide two of the most efficient methods of welding silicon bronze or aluminum bronze that have ever been developed.

3. Specialized techniques and procedures are sometimes required for joining these alloys to other dissimilar metals. Consequently, proficiency in the consistent production of quality welds requires the proper instruction and training of operators.

Acknowledgment

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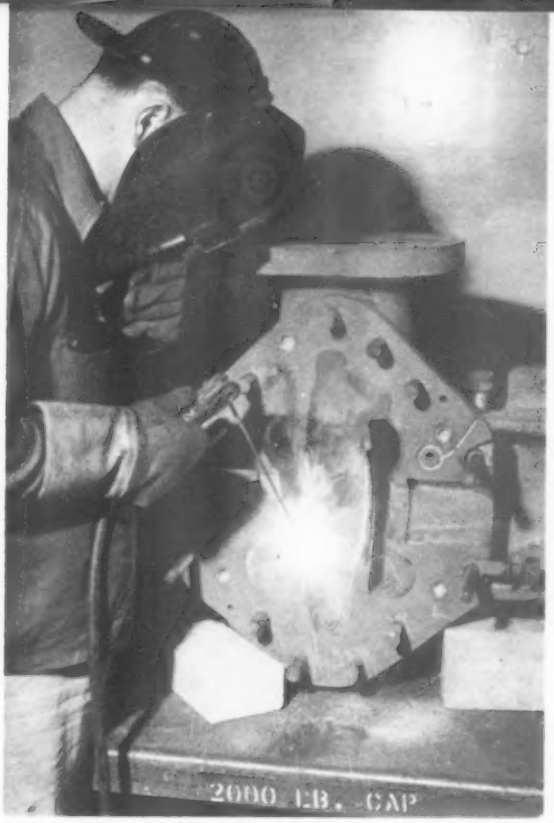

Building up by welding of wearing ring seat on cast steel centrifugal pump casing

CASTING WELDMENTS IN A PETROLEUM REFINERY

An evaluation of the weldability of some typical alloy-steel castings used as integral parts of process piping and auxiliary equipment

BY J. BLAND, C. B. PARRISH AND R. C. WHEELER

J. Bland, is Head, Metals and Welding Section, Engineering Research Dept.; **C. B. Parrish** is Head Engineer, Engineering Division; and **R. C. Wheeler** is Asst. Supt., Mechanical Division, Standard Oil Co., Whiting, Ind.

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ABSTRACT. Several typical applications of casting weldments in a petroleum refinery are described in this paper. Results of some limited studies of the weldability characteristics of low and intermediate chromium-molybdenum alloy-steel castings are discussed.

Castings which meet specification requirements for chemistry and tensile properties, in addition to being virtually free from casting defects, are satisfactory components of petroleum refining equipment and process lines. Certain maintenance and repair problems associated with casting weldments are reviewed. Typical examples of repair and maintenance of casting weldments are discussed.

Introduction

Castings, such as pump bodies and various types of fittings and flanges for lines, have been used in petroleum refineries for a long time. All of these items, from time to time, have posed maintenance problems, and any successful repair had to be accomplished by welding. The term welding also should be considered to include braze welding with a nonferrous filler metal, in addition to oxyacetylene welding with cast-iron filler metal.

The rapid development of petroleum refining processes has been accompanied by increases in temperatures and pressures of operation. Consequently, the use of cast iron has diminished considerably. Even the use of plain-carbon or alloy-steel castings has required a careful evaluation of their utility and their ability to be fabricated into the process systems which were required. Concurrently, it was considered necessary to evaluate the weldability of some typical alloy-steel castings, in order to compare their utility with that of similar forgings or weldments for such items as welding elbows, tees and other pressure fittings.

The use of casting weldments in a petroleum refinery is a somewhat different situation. For the purpose of this paper, such items as machines, tools or other maintenance equipment, many of which are being made today as casting weldments, will not be discussed. This paper will be concerned, however, with castings used as integral parts of process piping or auxiliary equipment. In addition, some discussion will be included concerning the welding repair of many types of castings encountered in a petroleum refinery.

Study of Cast Fittings for Process Lines

The steam-power industry, for a long time, has welded cast low-alloy steel valve bodies into high-pressure high-temperature steam lines. Many of the newer power stations in refineries also incorporate cast-steel valve bodies in their steam lines. However, the use of castings integrally welded in process lines, at least in a petroleum refinery, is of more recent origin. Several years ago an investigation was made of the weldability of a typical alloy-steel casting. The casting was a nominal 2% chromium-½% molybdenum alloy steel (ASTM-A157, Grade C-3A) in the shape of a tee fitting, for use with 5-in. Schedule 160 piping (ASTM-A335, Grade P3b). Three experimental welds were made between the outlets of the tee fittings and the similar nominal-analysis wrought pipe. These welds were made with different combinations of preheat and postheat treatment. The welds were made using a nominal

Table 1—Chemical Analyses of Materials Used in the Welds

Item	C	Mn	P	S	Si	Cr	Mo	Nominal analysis
Cast tee	0.15	0.78	0.030	0.024	0.43	2.04	0.36	2Cr–½Mo
Pipe	0.14	0.40	0.011	0.033	0.27	2.04	0.57	2Cr–½Mo
Weld metal	0.07	0.74	0.014	0.028	0.24	2.57	1.40	2½Cr–1Mo

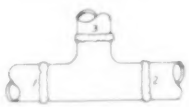
2¼% chromium 1% molybdenum low-hydrogen electrode (AWS-A5.5, E9016-B3). Chemical analyses of the casting, the wrought pipe and the weld-metal deposit are shown in Table 1.

Weld No. 1 was made without preheat or postheat treatments, and the interpass temperature was, essentially, room temperature. Weld No. 2 was made using 450° F preheat and interpass temperature with no postheat treatment. Weld No. 3 was made using 450° F preheat and interpass temperature, allowed to cool to room temperature, followed by postheating at 1350° F for 1 hr. The results of some stress analyses of the welds and of hardness surveys and tensile tests across the welds are shown in Tables 2 to 4, inclusive.

The results of residual stress measurements, shown in Table 2, indicated that preheat was effective in reducing residual stresses in the weld deposit. No measurements were made on Weld No. 3; however, the low residual stresses in Weld No. 2 indicate that postheat treatment probably would be of little additional value if its primary purpose was stress relief.

Table 2—Welding Conditions* and Results of Residual-Stress Measurements of Tee Welds

Weld No.	Preheat and interpass temperature, °F	Postheat temperature, °F	Residual stresses in weld deposits, psi‡ — Circumferential	Longitudinal
1	None	None	+14,200	−20,500
2	450	None	+ 2,500	− 8,400
3	450	1350 (1 hr)		



* All welds made using ⅛-in. E9016-B3 electrodes at 160 amps DCRP.
† + indicates tensile stress; − indicates compressive stress.
‡ These values obtained using the Soete hole-drilling method.

Table 3—Hardness Survey of the Welds

Weld No.	Pipe — Base metal — Max	Pipe — Base metal — Avg.	Pipe — Heat-affected zone — Max	Pipe — Heat-affected zone — Avg.	Weld metal — Max	Weld metal — Avg.	Cast tee — Base metal — Max	Cast tee — Base metal — Avg.	Cast tee — Heat-affected zone — Max	Cast tee — Heat-affected zone — Avg.
	Brinell hardness*									
1	153	150	231	228	283	264	167	165	264	256
2	152	150	222	210	286	264	165	162	246	240
3	137	134	164	161	200	186	150	147	174	169

* Converted from Rockwell hardness data.

All reduced-section tensile-test specimens from the three welds failed in the pipe metal. Preheat treatment alone had little or no effect on ultimate strength or on ductility. Postheat treatment reduced the ultimate strength somewhat, and increased the ductility of the weldment slightly. In all cases, most of the elongation occurred in the base metal of the pipe material. The high strength and hardness of the weld-metal deposit reduced to extremely small or insignificant levels the measured amount of elongation occurring in the weld-metal deposit alone. Side-bend-test results for Welds No. 2 and No. 3 were satisfactory; the weld metal in Weld No. 1 was too rigid with respect to the base metal of both the wrought pipe and the casting to permit any evaluation in the side-bend test.

Table 4—Tensile Properties of Reduced-Section Specimens from Tee Welds

Weld No.	Ultimate strength, psi	Reduction of area, %	Elongation — Weld metal, %	Elongation — In 2 in., %	Fracture in
1	75,200	66	0	20	Pipe
2	73,800	68	0	21	Pipe
3	71,500	70	2	25	Pipe

It may be noted that no welding difficulties were encountered in the preparation in any of these test welds. The weldability characteristics of the 2% Cr 0.5% Mo alloy-steel cast tee appeared to be quite satisfactory.

Seal Welding of Tubes in Furnace Headers

The normal installation of tubes in refinery furnaces

Table 5—Chemical Analyses of Alloy Cast-Steel Blocks*

Grade	Chemical composition, % C	Mn	Si	P	S	Cr	Mo	Nominal analysis
WC1	0.20	0.71	0.54	0.022	0.036		0.57	CMo
WC6	0.13	0.55	0.42	0.018	0.035	1.00	0.50	1CrMo
WC9	0.10	0.66	0.35	0.017	0.013	2.36	1.00	2¼CrMo
C5	0.17	0.67	0.60	0.033	0.039	5.25	0.48	5CrMo
C12	0.11	0.44	0.42	0.016	0.028	8.66	1.16	9CrMo

* Manufacturer's data.

Table 6—Tensile Properties and Hardness of Alloy Cast-Steel Blocks*†

Grade	Ultimate strength, psi	Yield strength, psi	Elongation in 2 in., %	Reduction of area, %	Brinell hardness
WC1	95,000	61,300	25.8	53.3	163
WC6	90,500	58,750	24	46.7	182
WC9	87,500	53,000	25	60	174
C5	101,500	68,500	23	56.5	207
C12	90,250	60,500	26	63.5	179

* Manufacturer's data.

† Normalized at 1750° F 4 hr, air cooled, then, normalized at 1600° F 4 hr, air cooled; finally drawn between 1200-1300° F to required hardness.

includes rolling of the tube ends into the cast headers. Frequently this operation does not provide absolute tightness, so that a further expedient, that of seal welding the tube in the header, is required. In the past, seal welding generally was done using austenitic 25% Cr 20% Ni electrodes, particularly where low or intermediate chromium-molybdenum alloy furnace tubes were involved. It was believed that the use of the austenitic electrodes obviated the need for thermal treatments, especially postheat treatment, even for the air-hardening grades of the chromium-molybdenum alloys.

It had been reported that cracks developed in or adjacent to austenitic seal welds after service. This was not unexpected, in view of the difference between the coefficients of thermal expansion of the austenitic weld metal and the ferritic base metals. Comparable failures have been reported in similar austenitic-ferritic weldments subjected to thermal cycling. An investigation, therefore, was undertaken in order to determine whether currently available ferritic low-hydrogen electrodes could be used for seal welding of furnace tubes in headers without thermal treatments. In particular, the elimination of postheat treatment was considered to be important, in view of the inherent difficulty of effecting such treatments in the field.

In the following two sections, the abbreviated nominal analyses have been used; thus, a 1¼% Cr-½% Mo alloy is designated "1¼ CrMo."

Materials and Procedure

The materials used in this study included 5 grades of cast alloy-steel blocks corresponding to the furnace headers, and 5 grades of wrought alloy-steel pipes corresponding to the furnace tubes. The chemical analyses and tensile properties of the cast alloy-steel blocks are listed in Tables 5 and 6. The wrought alloy-steel pipes were stock materials conforming to the nominal grades as indicated in Table 7.

The filler metals were standard stock electrodes. Table 8 lists the chemical analyses of the all-weld metal deposits made using these electrodes. It should be noted that variations from those analyses will occur, depending on the extent of base-metal dilution of the fillet welds.

The mating surfaces of the cast block and the wrought pipe were machined flat, in order to provide maximum restraint to the fillet welds. Two fillet welds were made for each of the various combinations of filler metal, cast alloy and wrought alloy base metals, and preheat

Table 7—Chemical Analyses of Pipes

Nominal analysis	Chemical composition, % C	Mn	P	S	Si	Cr	Mo
CMo	0.15	0.65	0.012	0.022	0.16		0.55
1¼CrMo	0.16	0.47	0.011	0.022	0.78	1.23	0.61
2¼CrMo	0.13	0.38	0.009	0.015	0.26	2.21	1.14
5CrMo	0.16	0.40	0.011	0.012	0.32	4.66	0.53
7CrMo	0.125	0.44	0.022	0.010	0.71	6.77	0.58

Table 8—Chemical Analyses of Filler Metals

Code	Nominal analysis	C	Mn	P	S	Si	Cr	Mo	Ni
85	CrMo	0.08	0.38	0.018	0.036	0.19	...	0.49	...
1A	1¼CrMo	0.08	0.67	0.018	0.022	0.36	1.14	0.70	...
90	2¼CrMo	0.10	0.52	0.026	0.017	0.47	2.43	1.06	...
5M	5CrMo	0.06	0.55	0.014	0.012	0.24	5.19	0.59	...
7	7CrMo	0.07	1.22	0.018	0.036	0.40	6.36	0.55	...
25/20	25Cr-20Ni*	0.15	1.75	0.04 (max)	0.04 (max)	0.50	25	0.25 (max)	20

* Manufacturer's nominal analysis.

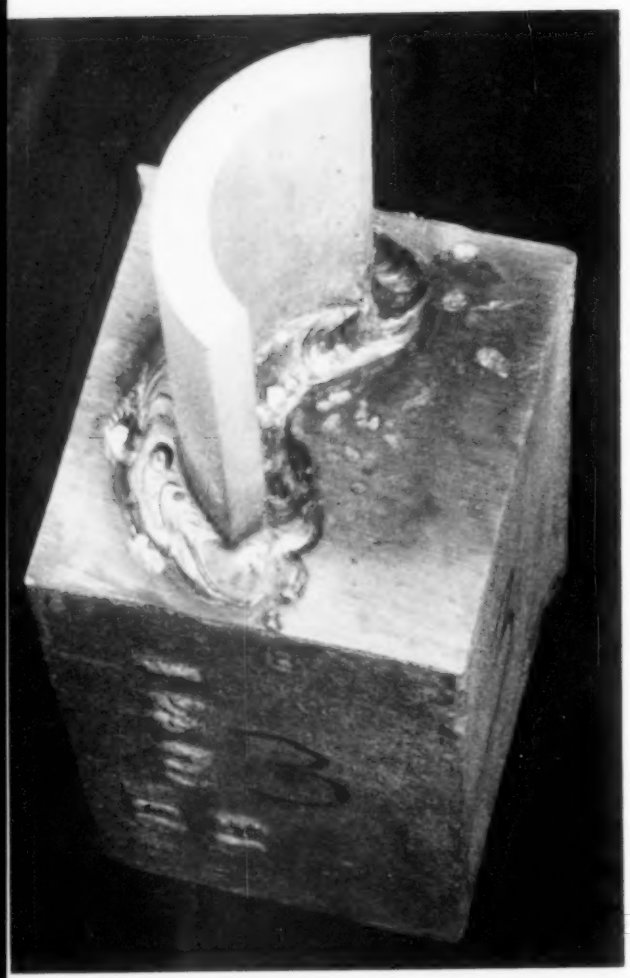


Fig. 1 Photograph of typical sample of welded assembly for study of seal welding of tubes in headers. Approximately X $^{2}/_{3}$

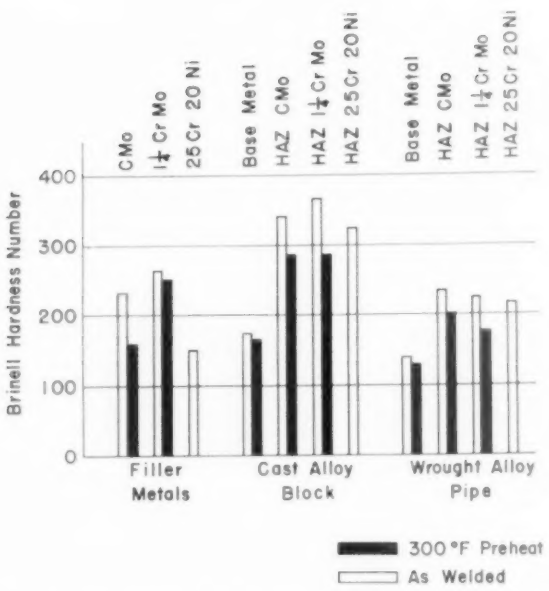


Fig. 2 Bar graph showing results of hardness surveys of filler metal, base metal and heat-affected zone for various combinations and preheat treatments, for the CMo header material

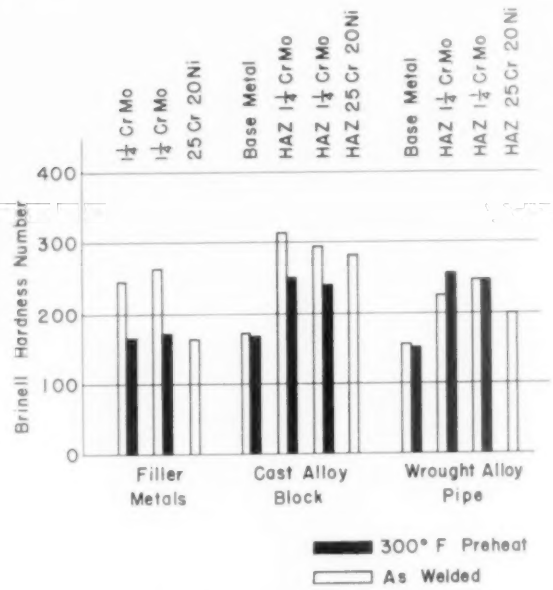


Fig. 3 Bar graph showing results of hardness surveys of filler metal, base metal and heat-affected zone for various combinations and preheat treatments, for the 1 CrMo material

conditions. In each case the first fillet was deposited at the ID surface of the pipe; the second weld was deposited at the OD surface of the pipe. Preheating, where used, was done by placing the assembly in a furnace held at the indicated temperature. A photograph of a typical weld is shown in Fig. 1.

After welding, the fillet welds were sectioned for metallographic examination and hardness survey. In addition, each weld was checked for macrocracking by the magnetic-powder inspection method.

Results and Discussion

Fillet welds were made with ferritic electrodes, without preheat or postheat treatments; with ferritic electrodes, with 300° F preheat and no postheat treatment; and with austenitic (stainless-steel) electrodes, without preheat or postheat treatments. The magnetic-particle inspection of all combinations of cast header material, pipe material and filler metals failed to reveal any cracks in the weld metal or base metal. In the case of the fillet welds made with austenitic electrodes, the base metals only were inspected by this method, since the austenitic weld metal is nonmagnetic.

Metallographic examination of cross-section specimens revealed only a few instances of fine cracks at the roots of some low-alloy ferritic fillet welds. In general, these cracks were located at areas exhibiting either incomplete penetration or slag entrapment. Also, these fine cracks were observed only on the welds made with-

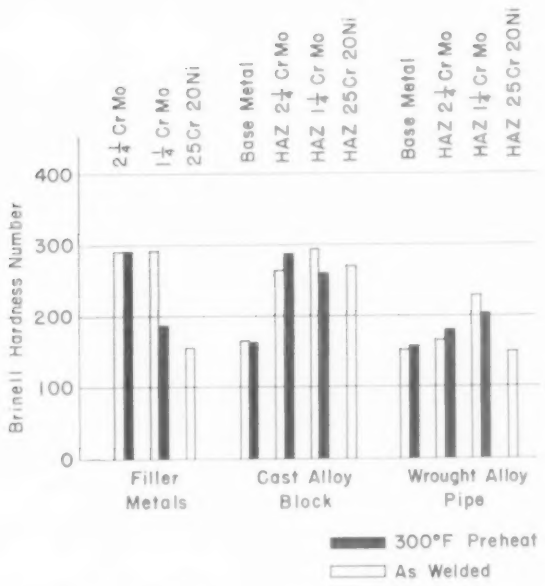


Fig. 4 Bar graph showing results of hardness surveys of filler metal, base metal and heat-affected zone for various combinations and preheat treatments, for the 2¼ CrMo material

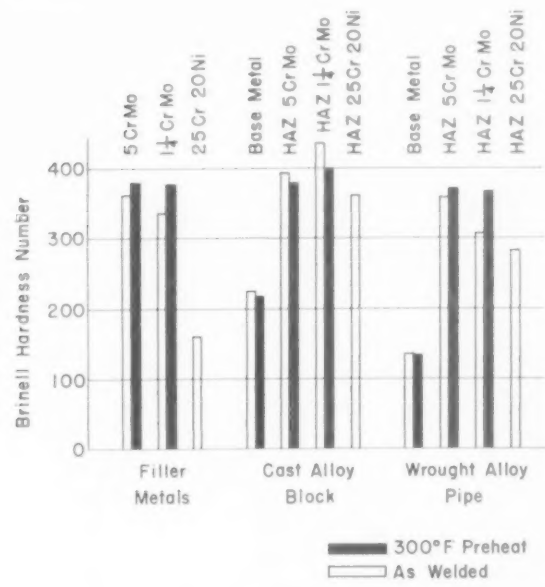


Fig. 5 Bar graph showing results of hardness surveys of filler metal, base metal and heat-affected zone for various combinations and preheat treatments, for the 5 CrMo material

out preheat or postheat treatments. It is considered that these fine cracks are more significantly the result of welder technique than the inherent characteristic of the particular weld metal. This is established also by the satisfactory results obtained using the higher alloy, more air-hardening grades of ferritic electrodes. The appearance of the 300° F-preheated ferritic-electrode welds was similar to that of the as-welded fillet welds

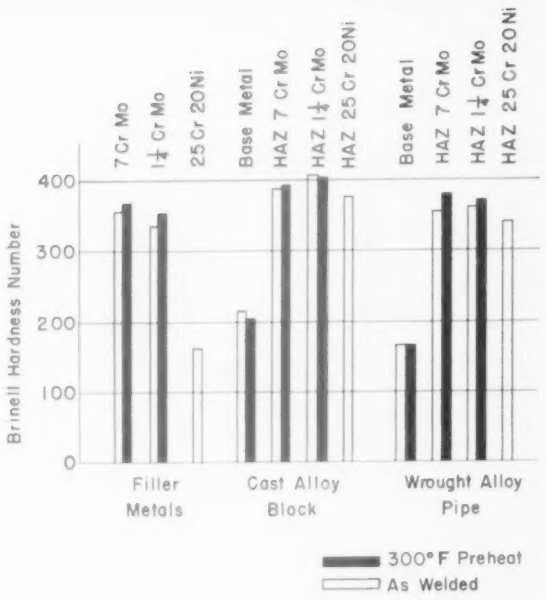


Fig. 6 Bar graph showing results of hardness surveys of filler metal, base metal and heat-affected zone for various combinations and preheat treatments, for the 9 CrMo material

except for the lack of defects noted above.

Figures 2 to 6 inclusive are bar graphs of the results of hardness surveys across the various fillet welds. It will be noted, in general, that the hardnesses of the wrought or cast base metals are relatively unaffected by the 300° F preheat treatment. The cast header material, for any nominal analysis, is somewhat harder than the wrought pipe material. Only the CMo and 1 CrMo cast header material heat-affected zone and filler metals show significantly lower hardnesses with the 300° F preheat treatment, compared with as-welded hardnesses.

Heat-affected zone hardnesses of the cast alloy materials generally are higher than those of similar (nominal) analyses of wrought pipe. It will be noted, also, that the heat-affected zone of either the cast or wrought base metal essentially has the same as-welded hardness regardless of the filler metal used. This is understandable, in view of the fact that all welds were made with about equal heat inputs (comparable speeds, arc voltages and currents). Consequently, the base-metal heat-affected zone exhibits a similar response, in terms of metallurgical changes, for the heat cycle to which it has been subjected.

The past usage of austenitic stainless-steel filler metal for seal welds on furnace tubes appears to have been based on the avoidance of weld-metal cracking. The high ductility of austenitic weld metals permits shrinkage strains to be absorbed by the weld, thus minimizing as-welded cracking. However, as previously noted, the austenitic weld-ferritic base-metal composite frequently developed service cracks because of differences in thermal coefficients of expansion.

The use of the low-hydrogen low-alloy electrodes

will provide weld metal with adequate ductility for as-welded shrinkage strains. Also, the fact that both the weld and base metals are ferritic should insure relative freedom from service cracks resulting from thermal cycling.

The high hardnesses of the base-metal heat-affected zone, either for the wrought or cast alloys containing 2¼ CrMo or more, are not detrimental by themselves. These hardnesses are obtained even if austenitic electrodes are used, and no serious objection has been expressed for this usage. Also, service conditions, which usually are at relatively high temperatures, will gradually temper these hard structures down to reasonable (say below 250 Brinell) hardness levels.

One criterion which may influence the selection of the electrode for seal welding is corrosion (or scaling) resistance. Undoubtedly, the austenitic weld metal would exhibit maximum corrosion resistance. However, the header ends of furnace tubes frequently are at lower temperatures than the middle portions, so that lower alloy contents at the headers might exhibit adequate resistance to corrosion. Normally, the seal welds would not be subjected to sealing conditions, being exposed only to the process stream.

In addition, corrosion attack of the seal welds will not influence the structural stability of the furnace tube-header assembly. No strength factor is taken for these seal welds. Repair, if necessary, of leaking ferritic seal welds is considered to be much less difficult than for austenitic welds.

Applications of Cast Weldments

Typical refinery applications of cast weldments include cast elbows, return bends and valve bodies in piping systems; compressor and pump casings and impellers, and furnace welding return bends and roll-type headers fabricated by welding cast components of ferrous or nonferrous materials. Cast steel-pipe welding fittings, including ells, tees, valves and specials, in sizes up to 18 in., have been installed in piping systems using conventional piping joint details.

Large quantities of sulphuric acid and acid sludges are handled in the refinery. Weak acids and acid sludges ordinarily are pumped in red-brass lines with welded construction generally being preferred over screwed construction. Figures 7 and 8 show typical weldments of cast red-brass tees, elbows and flanges. Note the castings have been welded to wrought brass pipe (0.337-in. wall) as well as to other castings. These particular joints were inert-gas consumable-electrode arc welded using 0.035-in. diam aluminum-bronze (8% Al) filler wire. The shielding gas used was argon. The joint details were a 60-deg included-angle single vee with $\frac{1}{16}$- to $\frac{1}{8}$-in. root face and $\frac{1}{16}$-in. root gap. Until recently such joints were oxyacetylene welded with a low-fuming manganese-bronze filler rod. This technique presented a difficult preheat problem. Two oxyacetylene preheat torches were required which made the joint costly in manpower and uncomfortable for personnel.

Limited use has been made of cast welding components in pumps and compressors in the refinery. One

Fig. 7 Photograph of typical casting weldment of cast red-brass tees, elbows and flanges, and wrought red-brass pipe

Fig. 8 A closer view of a typical red-brass casting weldment involving wrought pipe, cast elbow and cast flanges

Fig. 9 Pump impeller fabricated by welding cast blades to a cast hub. Material is aluminum bronze. Weld metal is phosphorus bronze

well-known manufacturer of pumps and compressors furnishes cast steel multi-stage centrifugal compressor casings. The nozzles are fabricated from carbon-steel plate or pipe and are welded to the casing. In some designs, interstage diaphragm guides also are welded to the casings. Engineering details concerning these welds are not available.

An example of a pump impeller fabricated as a cast weldment is shown in Fig. 9. The impeller consists of cast aluminum bronze (10.5 Al; 3.5 Fe; balance Cu); the blades were welded to a hub of similar material with phosphor-bronze filler metal using a maximum preheat of 300° F, controlled by temperature-indicating crayons or pyrometers and heat-treated at 600° F for 5 hr. Welding has been done by either the tungsten-electrode inert-gas or the consumable-electrode inert-gas metal-arc welding processes.

Heat is supplied to the oil charge stock in most refinery units by pumping the oil through the coils of a fired furnace. These furnaces are similar to water tube steam boilers. The oil flows back and forth in pipe or tubing through the fire box of the furnace until it reaches the desired temperature. To effect this reversal of flow, 180-deg return bends connect adjacent paralled tubes. These return bends or headers almost invariably are castings. Typical installations include plain carbon steel, low, intermediate, and high-alloy ferritic steels and austenitic stainless steels. Frequently, especially in recent years, new furnace construction has utilized cast welding headers which are attached to the tubes by butt welding, in preference to cast headers into which the tubes are rolled. See Figs. 10 and 11 for examples of such installations. The material of the headers in the illustrations is 2¼% Cr 1% Mo (ASTM-A217, Grade WC9). Tubes are 8-in. OD, ⅜-in. minimum wall 2¼% Cr 1% no (ASTM A200, Grade T22) material. These butt welds were made with similar analysis electrodes (AWS A5.5, E9016-B3) with 500° F preheat and a 2-hr 1300–1400° F stress relief, followed by furnace cooling to 1000° F and air cooling to ambient temperature. "Hairpins" consisting of two tubes connected by a header, were made up on the ground and stress relieved in field-built heat-treating furnaces. Final welds were made in place in heat-treating furnaces built around several adjacent joints. All welds were magnetic-particle inspected and one weld in six was completely radiographed. Tubes and headers were beveled 37½ deg. The inside surface of the headers was beveled 2–3 deg for alignment purposes.

Other cast headers, as noted previously, are fastened to the tubes by mechanically expanding the tubes into serrations in the headers. Because of various requirements, some difficult-to-cast designs result. This problem is sometimes solved by butt welding two simplified castings together.

Welding Repairs to Castings

Many castings and casting weldments require repair after they have been in service because of cracking for various reasons, corrosion, erosion, mechanical wear or abrasion and discovery of casting defects. A discussion of several instances of the welding repair of these items is presented below.

Fluid catalytic cracking units utilize cast-steel slide valves to control the flow of catalyst. Cracks and casting defects were discovered in a number of 5% Cr ½% Mo slide-valve bodies after several years of service. The majority of the cracks found averaged ½ in. in depth, and varied from 2 to 6 in. in length. On several valve bodies, cracks were found to extend through the casting and as much as 6 in. in length, as shown in Fig. 12. Numerous defects, appearing as small pin holes on the surface, were investigated by chipping and were found to be sand inclusions and or spongy regions averaging ½ to ¾ in. in depth and

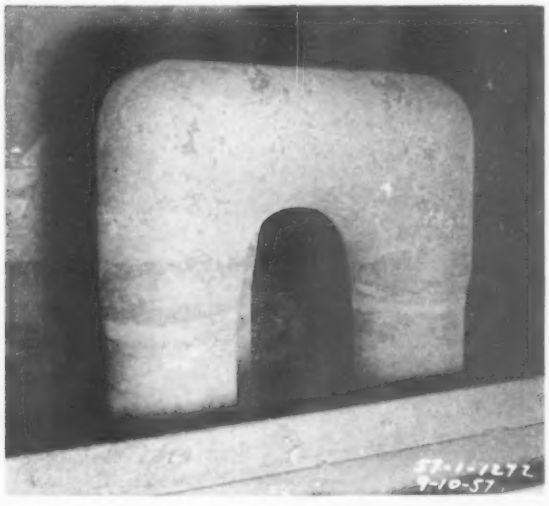


Fig. 10 Typical cast return header butt welded to furnace tubes. Material is 2¼% Cr – 1% Mo alloy steel

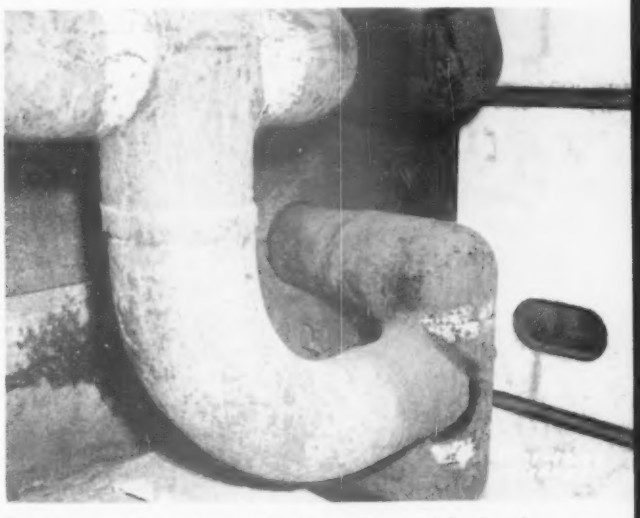


Fig. 11 Cast fittings butt welded in the furnace tube-header assemblies. Material is 2¼% Cr – 1% Mo alloy steel

Fig. 12 Photograph of cast 5% Cr – ½% Mo alloy-steel slide-valve body flange at chipped out area of crack through body thickness

Fig. 13 Photograph of cast 5% Cr – ½% Mo alloy-steel slide-valve body showing abundance of defective areas

from 2 to 3 sq in. in area. Another type of defect found appeared to be blow holes since the holes were smooth and there was no evidence of sand. Figure 13 shows the abundance of defects, including hot tears, which were removed from one casting. The hot-tear defect was common to all of these valves, but to a lesser extent, and appears to be a casting-defect characteristic of 5% Cr-½% Mo steel. Another type of casting defect repaired was found common to several valves. This

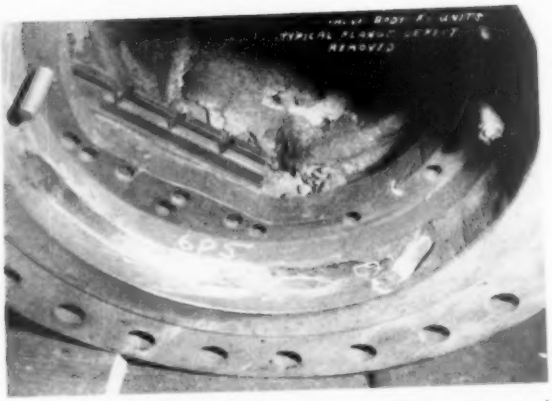


Fig. 14 Inside view of cast 5% Cr – ½% Mo alloy-steel slide-valve body showing extent of metal removal to eliminate cracks at the flange-bore surface

Fig. 15 Photograph of bronze impeller which had a crack in the blade-to-hub weld. The blade was broken off completely in transit to the shop for repairs

was a crack which sometimes extended completely around the inside (bore) surface of the flange (Fig. 14).

These 5% Cr-½% Mo valve bodies were torch preheated to 600° F before welding, and the temperature was maintained between 400 and 600° F while welding progressed. After welding was completed, the bodies were permitted to cool slowly. This was allowed so that all valve bodies could be heat-treated at the same time. Welding electrodes used were 5% Cr-½% Mo and 7% Cr-½% Mo; the type used depended on its availability. After welding, the valve bodies were heated to 600° F; then the temperature was increased at the rate of 200° F/hr up to 1350° F. The valves were then allowed to soak for 2 hr per in. of thickness, or a total of 6 hr. After soaking, the bodies were allowed to cool at a controlled rate of 100° F/hr to 600° F; then, they were allowed to furnace cool. The valve bodies were checked for cracks by magnetic-particle inspection after heat treatment.

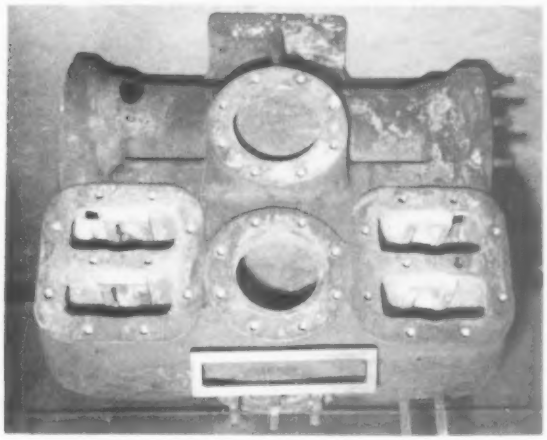


Fig. 16 Photograph of cast yellow-brass liquid end of a reciprocating pump, showing a loose valve seat on top and the valve seats installed by welding

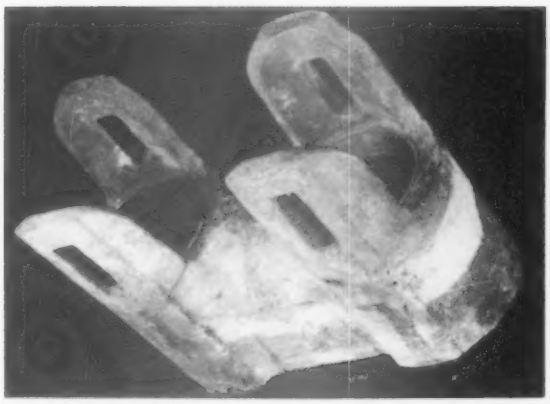


Fig. 17 Photograph of cast "mule-ear" header. Note crack at base of ear, lower left of photo, resulting from overstressing as a result of over-tightening and/or casting defects in the critical section

Carbon-moly and 18% Cr 8% Ni-Cb stainless-steel (Type 347) valve bodies have been repaired in a similar fashion. The carbon-moly valves normally have been preheated at 400° F and welded with C ½% Mo electrodes. The stress-relief procedure has consisted of heating from 600 to 1200° F at 200° F/hr maximum, holding at the soaking temperature for 1 hr per in. of thickness and cooling at a rate of 200° F/hr. The 18% Cr 8% Ni-Cb stainless valve bodies have been welded with Type 347 electrode with a post-weld heat treatment of 4 hr at 1600° F, followed by air cooling.

Approximately 65 cast carbon-moly welding elbows on a refinery unit developed leaks in casting defects during the hydrostatic tests prior to the start up of the unit. The elbows ranged in size from 10 to 18 in., and the defective areas from 2½ in. in diam to 6 x 13 in. These defects were chipped out and the repair made with an E7010 (C ½% Mo) electrode. A preheat of 400-600° F and postheat of 1200-1300° F was obtained with electrical-resistance heaters.

A cast government bronze (88 Cu, 8 Sn, 4 Zn) impeller, similar to the impeller shown in Fig. 9 except for the material of construction, has been repaired by welding on several occasions. On one occasion, the absence of weld metal was noticed at two points on the welds connecting the blades and the hub. Also, loss of metal was observed at the trailing edge and on the surface of the blade. The area at the missing weld metal and the areas of the more severe loss of metal were chipped out to clean metal and to form a suitable groove for welding. These areas were then repaired by the inert-gas tungsten-arc welding process. No preheat was maintained and the welding proceeded slowly enough so that the impeller temperature was not allowed to exceed 300° F.

On another occasion, the weld attaching one of the blades on a (government bronze) impeller was badly cracked. The blade was broken off completely in transit to the shop (Fig. 15). The edge of the blade was beveled for welding from both sides and installed in a jig to maintain correct alignment. A 400° F preheat was maintained during the inert-gas tungsten-arc welding. Filler-metal rod used was ⅛- and 3/16-in. silicon bronze. Considerable difficulty was encountered with cracking. The cause of the cracking was believed to be due to the original low-melting filler metal, as well as to the hot shortness of the silicon-bronze deposit. The defective metal was removed and the weld completed with only minor surface-cracking difficulties.

Figure 16 shows the cast yellow-brass liquid end of a reciprocating pump. The valve seats of this and similar pumps are battered and worn over a period of time until repairs are required. In the past, the seats were repaired by depositing weld metal (low-fuming manganese bronze) by oxyacetylene welding and subsequent machining. Presently, these pumps are being repaired by welding in new seats which have been cast separately and machined prior to their installation, using arc welding with an aluminum-bronze electrode. The figure shows the completed installation of new valve seats using this method. On top of the pump casting is a sample cast valve seat.

Cast furnace headers have been repaired for several different reasons. Occasionally it has been necessary to reduce the size of furnace tubes at a time when new carbon-steel headers were not immediately available. In order to utilize the existing carbon-steel headers, the tube seating surfaces were built up with carbon-steel weld metal and new smaller-diameter grooves machined. Badly worn or nicked serrations have been repaired in the same way.

A common type of header on refinery furnaces, especially in older construction, is a design commonly called "mule-ear" headers, for obvious reasons. Figure 17 shows a typical "mule-ear" header and the type of failure that often occurs when the ears are overstressed as a result of over-tightening and/or casting defects in the critical section. One such failure occurred on a 9% Cr-1% Mo header. The repair was effected in place by chipping and grinding both pieces to a vee groove

with an included angle approximating 60 deg for welding from one side. Lack of clearance between headers prevented welding from both sides. The work was preheated to 450° F with a propane torch; temperature-indicating crayons were used for temperature control. The weld was made with a 7% Cr-½% Mo welding electrode and stress relieved at 1350° F, again using a propane torch. The header was cooled to 600° F in 2 hr, insulated and allowed to cool to ambient temperature.

Welding repairs to castings are sometimes complicated or made impossible by casting defects. For instance, two cast columbium-stabilized 18% Cr-8% Ni (ASTM A-296, Grade CF-8C) alloy-steel terminal fittings on a refinery furnace developed leaks after service at the ring-type joint gasket surfaces. Exploratory survey of the defective areas was attempted on both castings by chipping out the porous areas and depositing Type 347 weld metal without heat treatment. The welding caused distortion at the seating surfaces so that machining was required. After machining, one flange satisfactorily passed the hydrostatic test but the other leaked more (adjacent to the repair) than it had previously. Apparently, the welding and machining operations had opened up passages in porous material which had remained undetected after chipping. A decision was made to cut off the flange and replace it with a Type 304 forged-steel flange. Subsequent destructive investigation of the defective flange revealed extensive porosity in the adjacent area which justified stopping the welding repairs. The new flange was welded to the remainder of the casting without heat treatment with a Type 347 electrode. The welding groove approximated a 75-deg included-angle single vee.

On one refinery unit, a large number of the 5% Cr-½% Mo furnace headers, which consist of two or more sections welded together, corroded preferentially at the welds. In some welds the corrosion uncovered a serious lack of penetration. In others the corrosion, in itself, was serious enough to require repair. Figure 18 shows, in a mirrored view, the corrosion at one of these welds. One header was repaired in place by grinding and depositing 5% Cr-½% Mo weld metal on the inside surface. The header was preheated to 400° F by means of electrical-resistance heaters. After the weld was completed the temperature was increased at the rate of 300° F hr to 1350° F, held for 2 hr and cooled at the same rate. The temperature was controlled by four thermocouples installed on the header. Accessibility of some of these header welds was extremely poor. Ten such headers were removed to the shop where the welds were removed by arc-air gouging. The rewelding and heat treatments were identical to the above described procedure except that the preheat temperature was accomplished with plant fuel gas torches and the postheat treatment was accomplished in a furnace.

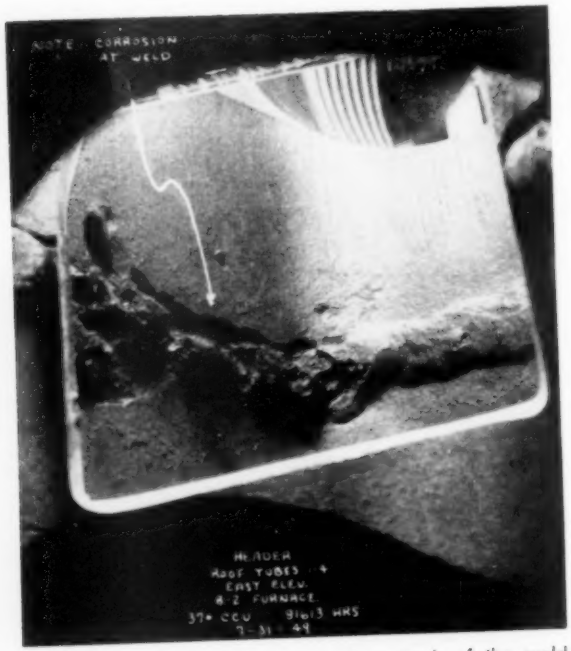


Fig. 18 A mirror view of corrosion attack of the weld joining sections of cast 5% Cr-½% Mo furnace headers

Summary

Casting weldments are being used to an increasing extent in process lines and equipment for oil refinery applications. The several studies which have been made of castings used in these services have demonstrated the satisfactory weldability characteristics of these items. It should be emphasized, however, that careful control of metal analyses and foundry practices must be exercised in order to obtain sound, weldable castings. When these are available, there is no hesitation in using them within the design and stress limitations imposed by applicable codes.

The use of casting weldments is dictated, of course, by the factors of economy and complexity of the item. In general, castings may be expected to be less expensive than forged or wrought items for similar applications. In some cases, the complexity of castings is such that it is more feasible to make one or more smaller, less complex castings or wrought parts and assemble these, by welding, into the completed equipment.

The maintenance of casting weldments imposes no greater problem, in general, than that inherent in the vessels, lines or other equipment encountered in a petroleum refinery. This is true, however, only if the material of the casting is readily weldable. Sufficient information as to the chemistry and prior history (as of heat treatments) of the casting should be available to provide a basis for the selection of the correct welding-procedure details.

Acknowledgment

The authors wish to acknowledge the assistance of many of the personnel in their respective departments in obtaining the data and information presented in this paper. The permission of the Standard Oil Co. (Indiana) to publish this paper also is gratefully acknowledged.

EVALUATION OF SPOT WELDS MADE THROUGH PRIMERS AND SEALERS

Primers and sealers found to have no detrimental effect on the weld strength of spot welds when welding is performed in accordance with proper procedure

BY B. A. SCHEVO

INTRODUCTION. Recorded test data regarding spot welding through primers and sealers are not readily available; therefore, basic practical research and development work were deemed necessary. The object of this investigation: to determine the effect of primers and sealers upon the weld strength of spot welds.

Material

The material under investigation and the equipment used consisted of:

1. Resistance spot welder, 3-phase, 200-kva rated capacity.
2. Mild steel, Specification MIL-S-13281, designated M.
3. Stainless steel, Specification QQ-S-00766, Class 430, designated S.
4. Chrome-molybdenum steel, Specification QQ-S-00627, designated C.
5. Low-alloy steel, Specification MIL-S-13281, Class B, Grade 2, designated N.
6. Sealers, Codes 1, 2, 3 and 4.
7. Primers, Codes 5, 7, 8, 9, 10, 11 and 12.
8. Vibration tester.

Test Procedure

Testing was performed in the following steps:

1. A technique was developed to spray the primers at the manufacturer's recommended film thicknesses.
2. Primed test panels were subjected to a salt-spray test, Federal Test Methods Standards No. 151, 17 July 1956, to determine if the primers were acceptable primers. Exposure to salt spray was for 96 hr.
3. Weld tests were performed on bare metal samples to determine machine settings.
4. The testpieces were welded to Specification MIL-W-6858.
5. The welded coupons were subjected to corrosion tests similar to that in 2 above and identified by the suffix letter "K."
6. Shear tests were conducted on lap-welded coupons to determine weld shear strength.
7. Leak tests, utilizing 70 oz of water per sample, were performed on troughs welded of mild steel and stainless steel. The test conditions were: (*a*) as welded; (*b*) baked at 200° F for 1 hr; (*c*) cooled at −40° F for 8 hr; (*d*) baked at 200° F for 1 hr, then cooled at −40°F for 8 hr; and (*e*) vibration after (*a*) through (*d*) above. The water leak tests were performed after samples had returned to room temperature.
8. Fatigue tests were conducted on primed and sealed test coupons and sealed troughs.
   (*a*) For coupons: double amplitude of 0.017 ± 0.010 in.
   Frequency: 30 cps. Duration of test: to failure.
   (*b*) For troughs: double amplitude of 0.020 ± 0.010 in.
   Frequency: 30 cps. Duration of test: 1 hr.

Results and Discussion

Test panels were sprayed with each of the primers and subjected to salt, spray tests as stated in "Test Procedure." Primer No. 5 was the only primer that met test requirements. Because primers Nos. 7 through 12 failed to meet the specification requirements, they could not be considered as satisfactory primers, and were therefore discarded and not used for any further testing.

The resistance-welding machine was adjusted for welding the particular types and thicknesses of steel to obtain the following shear strength values of Military Specification MIL-W-6858, Amendment 1, 12 June 1951, "Welding, Low Carbon Steels, Austenitic Steels, and Nickel Alloys, Spot and Seam":

Material	*Thickness*	*Minimum shear, lb/weld*
Mild steel (M)	0.062/0.062	2120
	0.099/0.099	4070
4130 steel (C)	0.062/0.062	3715
	0.098/0.098	7050
Stainless steel (S)	0.062/0.062	2530
	0.078/0.078	3580
Low-alloy steel (N)	0.052/0.052	1583
	0.105/0.105	4326

B. A. Schevo is associated with the Ordnance Tank-Automotive Command at the Detroit Arsenal.

Paper presented at 1958 AWS Annual Spring Meeting in St. Louis, Mo., April 14-18.

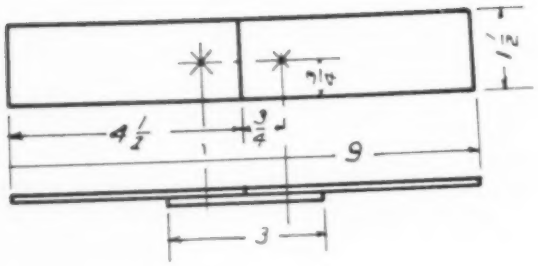


Fig. 1 Spot-weld coupon

Fig. 2 Trough details

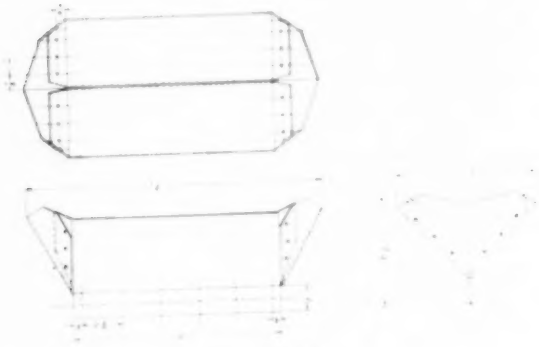


Fig. 3 Trough—leak test assembly

Table 1—Physical Condition of Sealers

Sealer	*Condition at room temperature*
1	Soft, putty-like
2	Runny-like soft grease
3	Soft, sticky
4	Soft, slightly tacky

After receiving treatment and returning to room temperature

Sealer	*Baked at 200° F*	*Subjected to −50° F*	*Baked at 200° F, Subjected to −50° F*
1	Normal	Normal	Normal
2	Hard-shrunk	Hard-shrunk	Hard-shrunk
3	Normal	Normal	Normal
4	Normal	Normal	Normal

NOTE: Normal—no change in texture or consistency from original.

Welding through the primer was performed after the primer had air-dried overnight. Welding through the sealer was performed shortly after the sealer was removed from its container and applied to the test coupons. The primer and the sealers were applied to the faying surfaces only.

The test samples were those shown in Figs. 1, 2 and 3.

Welding through the primer and sealers caused mild flashing at the weld but it was insufficient to affect materially weld shear strength. The welded coupons of primed and sealed specimens were subjected to corrosion tests as outlined in Federal Test Method Standard No. 151, and afterwards shear tested. The results showed that the requirements of Military Specification MIL-W-6858 can be met when welding is performed through primers or sealers.

The mild and stainless steels only were welded into troughs. These troughs were subjected to test conditions as listed in "Test Procedure." The results of the as-welded samples show that Sealer No. 2 produced more leaks than the other three sealers. The physical condition of the sealers, before and after testing, is listed in Table 1.

After vibration (fatigue) testing, water leaks were prevalent in many of the troughs. Three troughs had been made for each test condition. Leaking in corners was quite common because design of the trough did not permit welding at the corners. It is felt that these corner leaks should be disregarded. Sealers can seal large holes of approximately $^1/_{64}$ sq in. area. Welding was started at one end of a trough and continued to the other end. Examination of the results show Sealers Nos. 3 and 4 to be superior to Sealers Nos. 1 and 2 based on the tests to which they were subjected. Satisfactory welds were produced through all the sealers tested.

Photomacrographs of cross sections, representative of welds through the primer and sealers, are shown in Figs. 4 and 5. Identification, in the figures, is by thickness and alloy of metal since no great differences in appearance existed because of coatings on the faying surfaces. The actual samples in the photomacrographs are: Fig. 4, LM6, HM3, LC3, HC1; Fig. 5, LS4, HS1, LX1, HX5.

Welding through the sealers was a messy job. Occasionally expulsion of a sealer splattered the operator's hands and clothing. Unprotected hands could very easily be burned. Even when utmost care was exercised, the welding electrodes became smeared by the sealers.

Fatigue testing of spot-welded coupons and troughs did not produce any weld failures. The only failures present were in the coupon base metal and consisted of a break, adjacent to the spot, passing through the weld heat-affected area.

A few of the specimens fractured in the area adjacent to the tightly clamped end. The opposite ends were confined in a manner to limit vertical movement but allow for the small horizontal movement caused by the bending of the specimen. See Figs. 6 and 7 for the mounting of the test coupons.

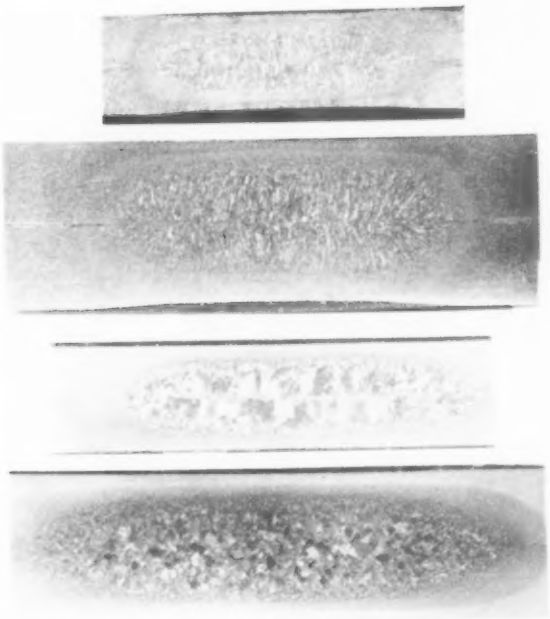


Fig. 4 Spot welds. Top to bottom—LM, HM, LC, HC

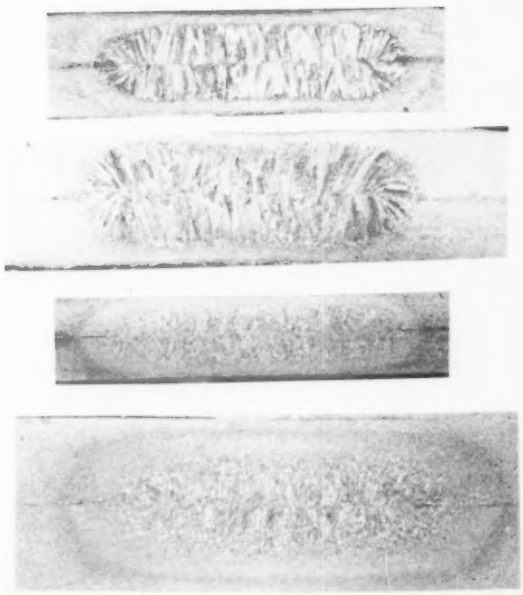


Fig. 5 Spot welds Top to bottom—LS, HS, LN, HN

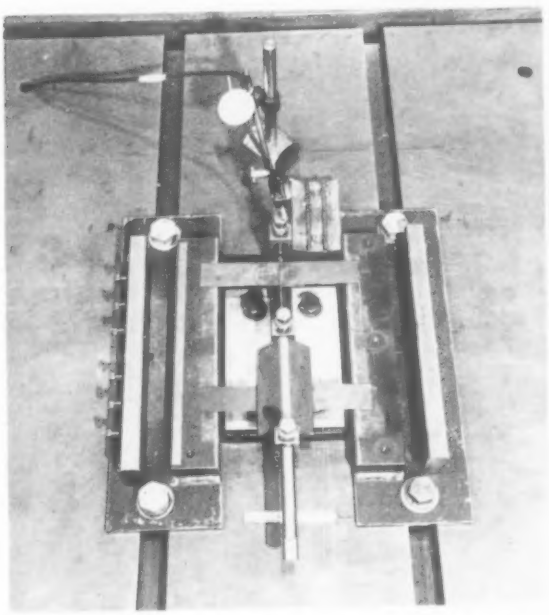


Fig. 6 Spot-weld fatigue test. Coupon-type fixture

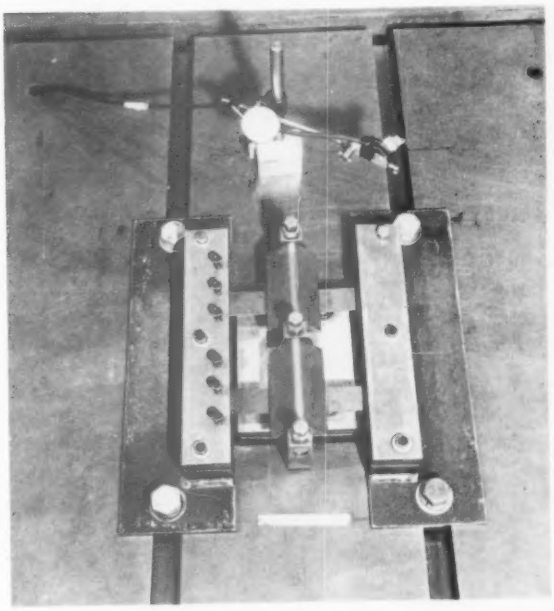


Fig. 7 Spot-weld fatigue test. Coupon-type fixture

The coupon specimens which had been subjected to corrosion, Code K, were not vibration-tested because the noncorroded specimens had not given a definite pattern of test results.

Both the light- and heavy-gage coupons were tested at the same double amplitude of 0.170 ± 0.010 in. The frequency of vibration was 30 cps. As specimens fractured, new specimens replaced the old ones, and the test continued. The numbers of vibration cycles required to cause fracture are listed in Table 2. The results did not show any distinctive pattern which would indicate the effect of various sealers or primers on strength of spot welds. There was, however, a fairly definite pattern of vibration resistance shown by the four types of steel, being particularly more apparent in the heavy than light-gage steels. Primers were not applied to the stainless steel. The LS2, LS3 and LS6 samples were not tested because they were too short to

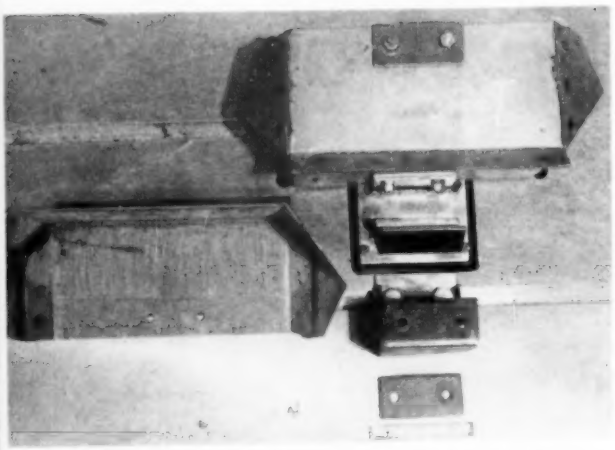


Fig. 8 Spot-weld fatigue test. Trough-type fixture

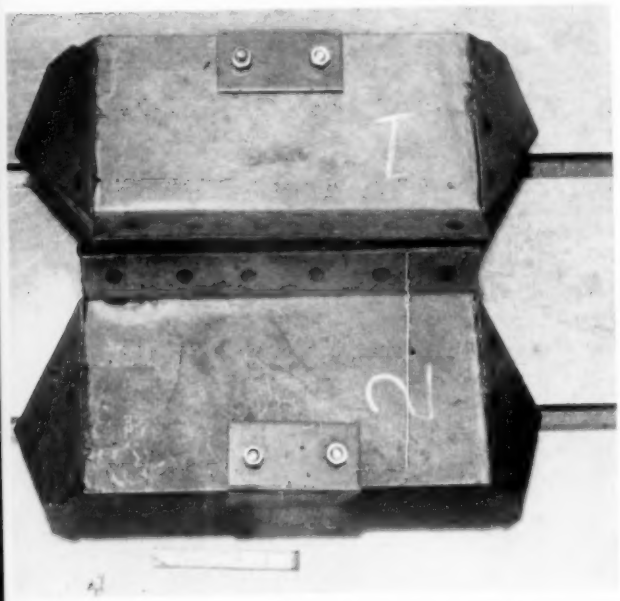


Fig. 9 Spot-weld fatigue test. Trough-type fixture

Table 2—Spot-Weld Fatigue Life in 1000 Cycles

Coating	*LM*	*LS*	*LC*	*LN*	*HM*	*HS*	*HC*	*HN*
Sealer No. 1	108	68	144	133	63	145	216	70
2	108		177	158	90	236	216	41
3	82		76	97	64	190	211	75
4	53	54	55	94	72	216	189	87
Primer 5	71		93	28	110		169	66
Bare 6	100		80	63	92	216	142	59
Average	87	61	104	95	82	202	190	63

NOTE: *L*—Light gage. *C*—4130 steel.
H—Heavy gage. *S*—430 stainless steel.
M—Mild steel. *N*—Low-alloy steel.

fit into the test fixture. The bare samples, Code No. 6, were tested as a control to provide a reference for comparison with the sealers and primers.

The trough specimens were mounted for testing as shown in Figs. 8 and 9. All troughs withstood a vibration at the rate of 30 cps, with a double amplitude of 0.200 in., for a period of 1 hr. Exceptions were the first few troughs tested which developed cracks adjacent to the reinforcing plate on top of the mounting fixture. The size of the reinforcing plate was increased to eliminate the cracking and increase the flexing action at the weld point.

Chemical analyses of the steels employed in the tests are listed in Table 3.

Summary

1. Spot welding was performed satisfactorily through one primer and four sealers.

2. Sealers satisfactorily prevent water leaks on joints which have had sealers applied to the faying surfaces prior to spot welding.

Conclusions

Primers and sealers have no detrimental effect on the weld strength of spot welds when the welding is performed according to Specification MIL-W-6858, Amendment 1, 12 June 1951, "Welding, Low Carbon Steels, Austenitic Steels, and Nickel Alloys, Spot and Seam."

Acknowledgment

The author thanks T. Binkley, A. Hayes, and L. Saxon of Ordnance Tank Automotive Command, for their cooperation.

Table 3—Chemical Analysis of Test Steels

	Type Steel							
Element	*LM*	*HM*	*LC*	*HC*	*LS*	*HS*	*LN*	*HN*
Carbon	0.07	0.06	0.33	0.29	0.11	0.11	0.07	0.15
Manganese	0.27	0.39	0.55	0.50	0.45	0.42	0.38	0.37
Phosphorus	0.016	0.012	0.011	0.013	0.018	0.017	0.010	0.011
Silicon	0.00	0.00	0.27	0.25	0.19	0.50	0.00	0.26
Sulfur	0.013	0.016	0.014	0.030	0.012	0.011	0.014	0.031
Chromium	0.02	0.04	0.96	0.80	16.00	16.60	0.02	0.03
Nickel	0.03	tr	0.16	0.13	0.38	0.33	0.11	0.12
Molybdenum	0.04	0.03	0.25	0.24	0.03	0.03	0.04	0.03

NOTE: *L*—Light gage. *C*—4130 steel.
H—Heavy gage. *S*—430 stainless steel.
M—Mild steel. *N*—Low-alloy steel.

FIRST ALUMINUM TUGBOAT FEATURES ALL-WELDED CONSTRUCTION

The first aluminum tugboat to be built in the United States and the first aluminum vessel of any type to be certified by the American Bureau of Shipping is now undergoing trials following christening in New Orleans (Fig. 1).

The vessel, named the *M/V Sumter*, was built by Bryant Boats, Inc., of Bayou LaBatre, Ala., in cooperation with Kaiser Aluminum. It is a 55-ft all-welded boat, designed for use in the bayous and marshland oil fields of Southern Louisiana. Its shallow 4½-ft draft, made possible by its aluminum construction, will permit its use in waters too shallow for conventional tugs of this size. Its power plant consists of two GM 6-110 model diesel engines.

Constructed of corrosion-resistant, high-strength weldable alloys 5083 and 5086, the aluminum vessel offers, in addition to its shallow draft, the advantages of long life relatively free of maintenance and economy of operation. Because of its aluminum construction, the boat is expected to experience less vibration and noise, reducing equipment wear and crew fatigue.

Based on a story by Kaiser Aluminum & Chemical Sales, Inc., Chicago, Ill.

Fig. 1 The *M/V Sumter* is the first aluminum tugboat to be built in the United States and the first aluminum vessel of any type to be certified by the American Bureau of Shipping. This all-welded shallow-draft vessel is designed for use in the bayous and marshland oil fields of Southern Louisiana

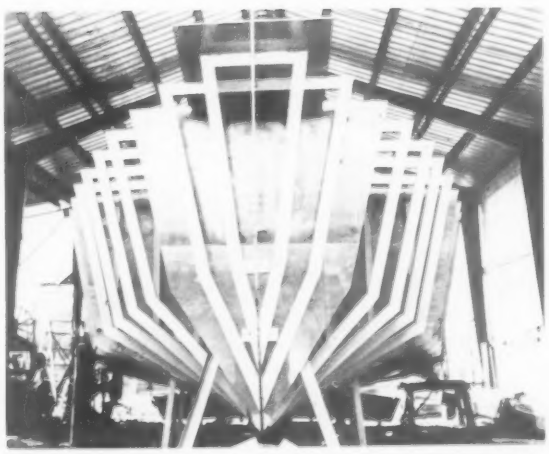


Fig. 2 This bow-on view of the *Sumter*, during construction, shows the aluminum framing and No. 1 bulkhead. The 55-ft vessel is made of the high-strength weldable alloys 5083 and 5086. Three-eighths inch aluminum plate was used for the hull and 5/16 in. for the deck and main bulkheads

Aluminum's light weight and ease of workability made possible substantial savings in construction costs. Fewer man-hours were required and the need for expensive heavy-duty equipment was eliminated.

The *Sumter* has facilities for a four-man crew. The main deckhouse has a galley, living quarters for two and shower. Aft of the wheelhouse, on the second deck, are quarters for master and mate, lockers and lavatory. Fuel tanks are located forward in the hull and water tanks aft.

Requirements of the American Bureau of Shipping were that the tug have equal strength and stiffness of steel, and these were incorporated into the design. The hull has 3/8-in. aluminum plate on the bottom and sides and 5/16-in. plate on deck. The stern tube was fabricated from 5-in. extra-heavy aluminum pipe. The tug is designed with six transverse watertight bulkheads and one center line watertight bulkhead.

The only nonaluminum parts in the boat are those in the engines plus the propeller and propeller shaft which are made of bronze. Electrolytic action is prevented by separating dissimilar metals. The tail-shaft of bronze is isolated from the aluminum hull by rubber bearings set in aluminum shells. The aluminum stuffing box was machined with adequate clearance to assure no contact with the bronze shaft.

Fig. 3 Welding aluminum plating to framing at chine inside the hull

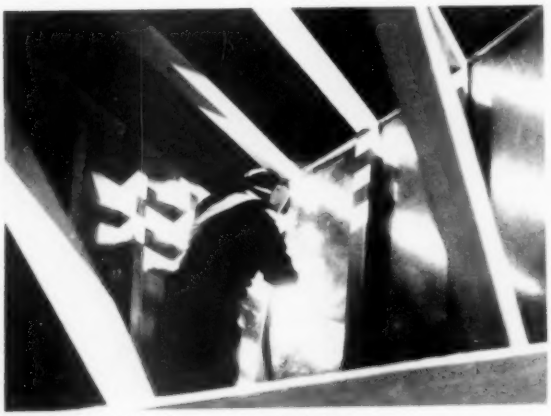


Fig. 4 Welding frames to hull plating

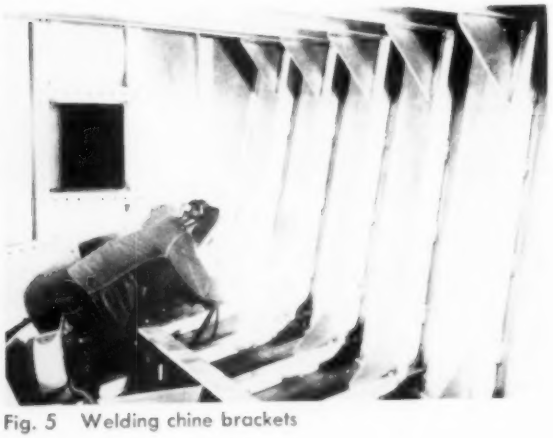


Fig. 5 Welding chine brackets

All bolts, setscrews and other fastening devices are of stainless steel, with the main engines installed on laminated plastic pads. Auxiliary generators, pumps and compressors have PAW tape applied with adhesive

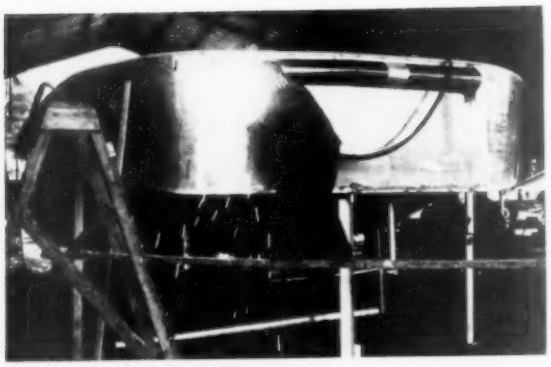


Fig. 6 Attaching stern bumper

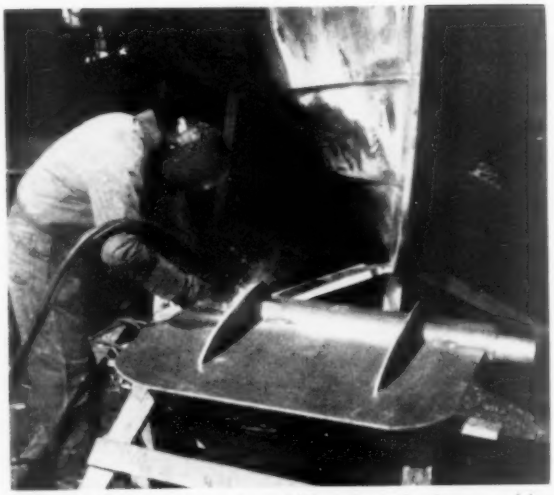


Fig. 7 Assembling and welding the aluminum rudder components

to the underside of their bases. Aluminum piping is insulated from the pumps, engines and other equipment by means of rubber or composition hose connections.

According to the fabricator, a number of advantages were realized during construction. Because of aluminum's light weight and ease of workability, Bryant Boats estimates hull construction required approximately 30% less man-hours than a comparable boat of steel. They found aluminum an ideal material for a relatively small yard with limited equipment.

Welders without previous aluminum experience were able to pass ABS certification with no difficulty and welding was much more rapid than with steel, according to Bryant. Cutting was accomplished by ordinary portable power saws.

Figures 2 through 7 illustrate some of the welding operations performed in the fabrication of the *Sumter*. The inert-gas-shielded metal-arc welding process was used.

NEW INLAND-WATERWAY TOWBOATS HAVE WELDED STAINLESS-STEEL HULLS

The first three inland waterway towboats with stainless-steel hulls have been designed and built by St. Louis Shipbuilding and Steel Co. for United States Steel Corp. (Figs. 1 through 4).

The unique vessels were built for service on the Ohio and Monongahela Rivers, at U. S. Steel's Clairton Works at Pittsburgh. Stainless steel was specified for all parts exposed to water from the main deck down, including shafting, struts and rudders.

The first towboat to be completed was the *USS-1*, a twin-screw, 600 craft of 70-ft length, 19-ft width and 8½-ft depth of hull. Eighteen tons of ¾-, ⅜-in. and ½-in. stainless-steel plate were used in the fabrication of the hull for this boat.

The final two boats, the *H. B. Jordan* and the *S. M. Jenks*, were larger vessels, each measuring 120 ft in length, 27 ft in width and 9 ft in hull depth. About 40 tons of stainless steel plating and 8 tons of stainless-steel forgings and castings were used in each of these 1280 hp, twin-screw tows.

A ton and a half of stainless-steel covered electrodes were used on the approximately 10,500 ft of welds deposited.

Based on a story by Electric Products Division of Vickers Inc., St. Louis, Mo.

Fig. 1 The *USS-1*, the first inland-waterway towboat with a stainless-steel hull

Fig. 2 Welder puts finishing touches on the stainless-steel hull of the *S.M. Jenks*, last of three stainless-steel towboats built for inland-waterway service

Fig. 3 All rudders, struts, shafting and propellers of the three towboats were also of welded stainless-steel construction

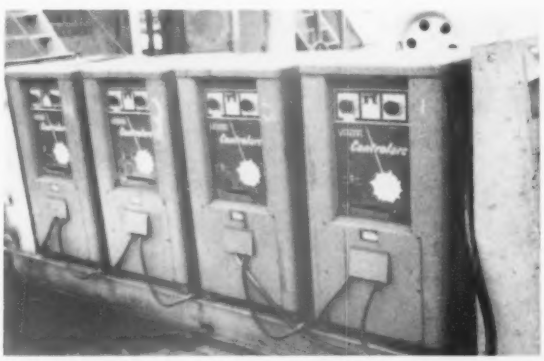


Fig. 4 Typical arc-welder installation used in the construction of the *USS-1*, the *H. B. Jordan* and the *S. M. Jenks*

FROM COILS OF STRIP STEEL TO CONTINUOUS-WELD PIPE

The operation of the continuous-weld pipe mills at the Aliquippa, Pa., Works of Jones & Laughlin Steel Corp. is a complicated process. Following is a step-by-step account of how quality continuous-weld pipe is made from coils of strip steel on the No. 1 continuous-weld mill (Figs. 1 through 5).

Coiled skelp is placed on an uncoiling spool and one end is fed into a roller leveler which levels or "irons" the skelp flat and straight in order that it will pass around the loop table, through the preheat furnace and through the welding furnace without kinking or bending.

As the tail end of one coil is reached, the starting end of another coil is run through the flash-welding machine

Based on a story by Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Fig. 1 Raw materials for the continuous-weld pipe mills at the Aliquippa, Pa., Works of Jones & Laughlin Steel Corp. are these coils of strip steel. The strip, which has been slit into widths ranging from 6 1/2 to 17 1/2 in., is produced on a 44-in. hot-strip mill in coils weighing as much as 18,000 lb

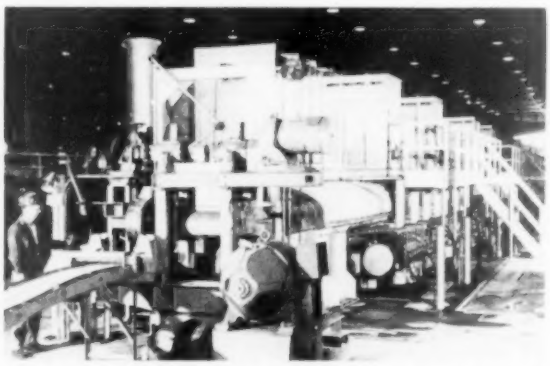


Fig. 2 Coiled skelp from the 44-in. hot strip mill is passed through this furnace, heated and then formed into pipe in continuous-weld pipe mill

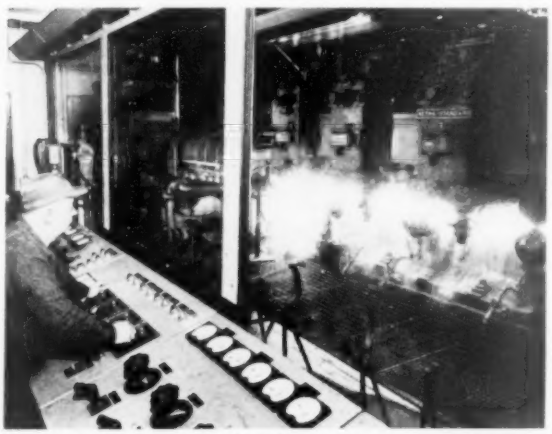


Fig. 3 Operator controlling the performance of the welding and forming stands from a pulpit

and the two coils joined together to make one continuous ribbon of skelp. After the weld is made, the skelp passes through a trimming machine where the excess metal from welding is removed. The skelp is then payed out by means of pinch rolls to fill up a loop table. This loop table permits welding of succeeding coils without a delay on the production line.

The skelp leaves the loop table and enters a 90-ft long preheat furnace, makes a complete loop in this furnace, then comes out and makes another complete loop prior to entering the welding furnace.

The welding furnace is 155 ft long and 33 in. wide. It is fired by small gas burners arranged along each side at intervals of 9 to 10 in. The skelp is brought to a welding temperature of 2450° F in approximately 30 sec in this furnace. However, the center of the skelp is kept several hundred degrees cooler than the edges to provide maximum pressure going through the welding roll.

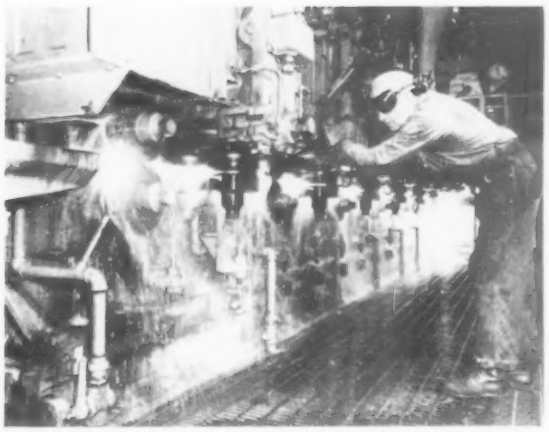


Fig. 4 Operator tightens one of the forming rolls on the continuous-weld pipe mill

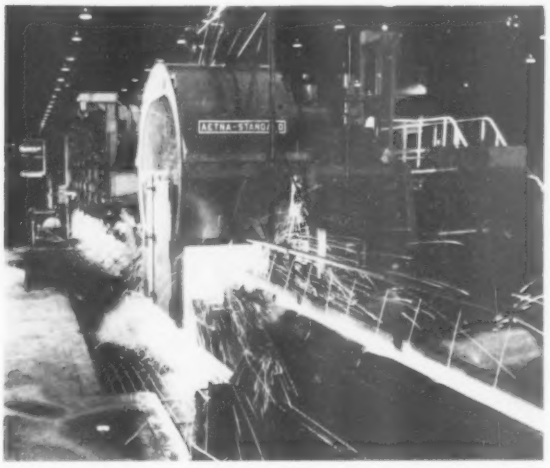


Fig. 5 As the welded pipe emerges from the rolls of the new continuous-weld pipe mills, it is cut to 42-ft lengths by this flying cutoff saw. The saw travels with the moving tube, hence the name "flying saw." The pipe is then split to 21-ft lengths, cooled and then inspected

As the skelp emerges from the furnace, jets of air are played on the edges to remove scale.

The pipe rides through the furnace on raised skids and is not subject to silica scale which adheres to conventional welded pipe whose skelp lies on the furnace hearth.

It then enters the forming and welding mill which consists of 14 stands on this smaller mill. The first stand forms the skelp in a downward curve approximating a circle about 270 deg closed. This formed skelp then passes through a "welding horn" which keeps it in position as it enters the second stand of rolls or welding pass.

Before the skelp is forced through the welding pass, jets of air are blown on the edges to increase temperature for stronger welds. The edges are squeezed together in the pass thus forming a weld.

After forming a weld, the pipe passes through the remaining stands where it is reduced in size without a change in the wall thickness.

The pipe then is forced through a sizing mill where uniform outside diameter is obtained and then cut to a 42-ft length. It then advances to a splitting saw where the 42-ft length may be cut into single lengths of 21 ft, a standard butt-weld length.

It is then carried on a screw-type cooling bed which feeds it into a water bosh for cooling. Following the bosh, the pipe goes to one of two straighteners.

When the pipe has been faced, it is subjected to its initial visual inspection on one of two inspection tables. One table is used for conduit and the other for other types of pipe.

As the pipe is inspected and accepted, it is hydrostatically tested in a new-type Schloemann Tester (Fig. 6). This tester, manufactured in Germany, simultaneously tests five tubes with water pressure up to 3000 psi.

The pipe is then transferred for either direct shipping, or additional processing such as galvanizing, threading or coupling.

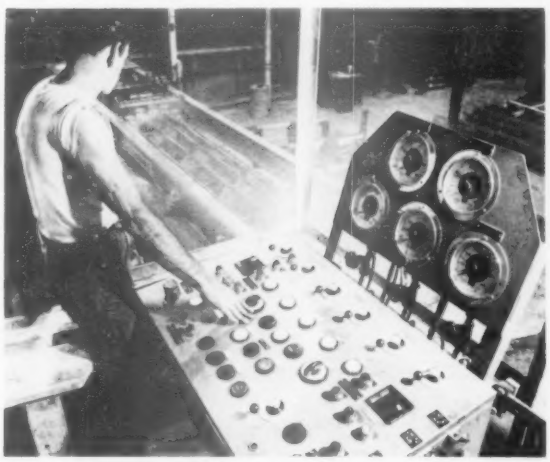


Fig. 6 Operating Schloemann hydrostatic tester, which simultaneously tests five tubes with water pressure up to 3000 psi

"CANNED" ENERGY FOR THE ATOMIC AGE

Radioactive materials—"canned" in inert-gas tungsten-arc welded containers—are being produced for commercial use at Oak Ridge National Laboratory, Oak Ridge, Tenn. Sealed in stainless-steel containers, these radioactive materials are used for special applications in hospitals and industrial plants.

During the last 10 years, the metals industry has become one of the largest users of radioisotopes. Applications range from basic metallurgical research on mineral flotation and slag-metal reactions to production operations like continuous noncontact gaging of rolled sheet and strip.

In the initial production run at the Laboratory, the remotely controlled tungsten-arc welding process was used to seal 34 capsules containing a total of 8000 curies (units) of radioactive cobalt.

Containers consists of two parts: an inner cylinder to hold the radioactive material and an outer stainless-steel jacket to hold the cylinder. The cylinder is sealed by a plug which is tungsten-arc welded in place. The outer jacket is then sealed by tungsten-arc welding a plug—fitted with a handling post—into the top of the jacket. The containers, which vary from 1/4 to 3 in. in diameter, may be used in a single unit or arranged in multiple units as an irradiation facility.

Since the containers are fabricated for commercial use, they need a dependable seal to prevent leakage of radioactive material. These materials, such as cesium-137, iridium-192, and cobalt-60, have been "canned" for some time by the Radioisotope Department of the Laboratory. But previous containers could not withstand exposure to high temperatures or corrosive solutions—necessary conditions of many medical and industrial applications.

To meet these exacting operating conditions, the Laboratory decided to make the containers with Type 316 stainless steel due to its weldability and resistance to corrosion from chloride salts and the atmosphere.

According to Oak Ridge, tungsten-arc welding was selected to replace previous methods, such as soldering and gasketing, for three main reasons: (1) argon-shielded tungsten-arc welds are stronger, more ductile, and more corrosion-resistant than welds made with ordinary arc-welding processes; (2) argon shielding avoids the need for a flux—eliminating the possibility of flux penetrating the container and causing corrosion; and (3) tungsten-arc welding is an outstanding process for welding stainless steel.

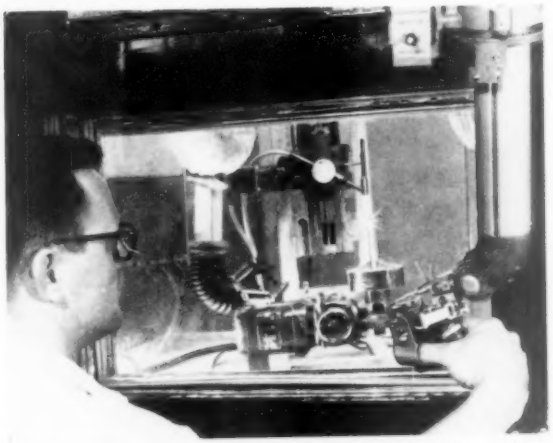


Fig. 1 Looking through several layers of special lead glass, a technician at Oak Ridge National Laboratory mechanically manipulates the tungsten-arc torch. Radioactive material is being sealed in a stainless-steel container for use in medical and industrial applications

The remotely controlled welding assembly is placed in a shielded cell equipped with mechanical manipulators as shown in Fig. 1. The assembly consists of a two-piece stainless-steel frame and motor-driven positioners for both the torch and containers. Controls for the motors are located outside the cell near a viewing window.

Containers are sealed with end or side circumferential welds (see Fig. 2). Test welds were made on several

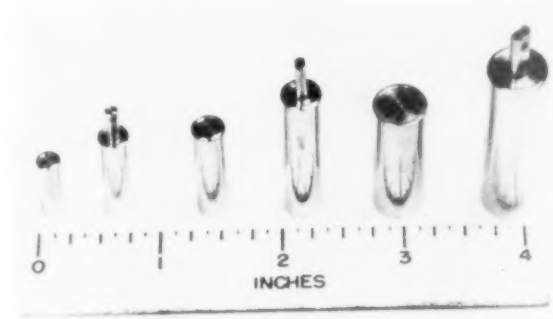


Fig. 2 These typical tungsten-arc-welded stainless-steel containers, filled with valuable radioactive materials, have a wall thickness of 0.020 in. Note the handling posts on the larger outer jackets

Based on a story by the Linde Co., New York, N. Y.

sizes of containers to establish proper operating conditions. The tungsten-arc welds passed stringent tests on weld penetration and the sealed containers were proved leaktight in a hot-water test.

The Laboratory found that four conditions were important in producing successful welds: (1) the surfaces to be welded should be clean; (2) the material inside the containers should be dry; (3) there should be virtually no clearance between the surfaces to be welded; and (4) the containers should be purged with the inert gas prior to welding.

Sealing radioactive materials by remotely controlled tungsten-arc welding is an important development in the Laboratory's radioisotope program. This same technique will be used in the future to seal large amounts of radioactive materials—soon to be produced in the nearly completed Fission Product Pilot Plant at Oak Ridge.

MOTORIZED SETUP SIMPLIFIES FLUXING OF FLANGED PARTS

Production engineers at Fenwal Inc., manufacturers of precision thermostatic controls and fire detectors, have devised an improved method for speeding up the fluxing of parts having awkward contours. A typical part, shown in Fig. 1, is a stainless-steel aircraft fire detector which has a triangular flange mounted on a cylindrical shell.

Based on a story by Handy & Harman, New York, N. Y.

Fig. 1 Fluxing of awkward contours is speeded up by motorized fixture which rotates part between a pair of brushes, fluxing both surfaces of flange simultaneously. Brushes are installed in the ends of a $\frac{1}{4}$-in. tube bent to form a handle by which operator controls flux application

The flux serves as a protective coating to prevent oxidizing of the stainless steel during subsequent torch brazing with AWS Specification B-Ag-1 alloy. Experience showed that the usual hand-brush method was too slow and tedious because of the awkward hand positions required to flux the upper and lower surfaces of the flange plus the areas of shell adjacent to the flange. Dipping was impractical because the assembly is open at the end.

Fenwal solved the problem with a motorized fixture which holds the part in the horizontal plane and rotates it between a pair of flux brushes. The end of the shell is inserted in a collet mounted on the shaft of a fractional horsepower motor, which rotates at a speed low enough (about 45 rpm) to prevent the flux from spraying off by centrifugal action. The collet ID is about $\frac{1}{8}$-in. oversize to permit the shell to be slipped in and out freely, and is long enough to support the shell for about $\frac{2}{3}$ of its length to prevent excessive sag or play during rotation.

The fluxing brushes are held in the ends of a $\frac{1}{4}$-in. tube bent around to straddle the flange. The brush holder, which pivots freely on an axle, is slightly overweighed at the front end, so that the brushes dip into the trough of flux when the operator releases the handle. In this manner, the brushes swing out of the way when the fixture is being loaded and are always covered with flux ready for use. The fluxing rate with this setup is about 8 sec per piece.

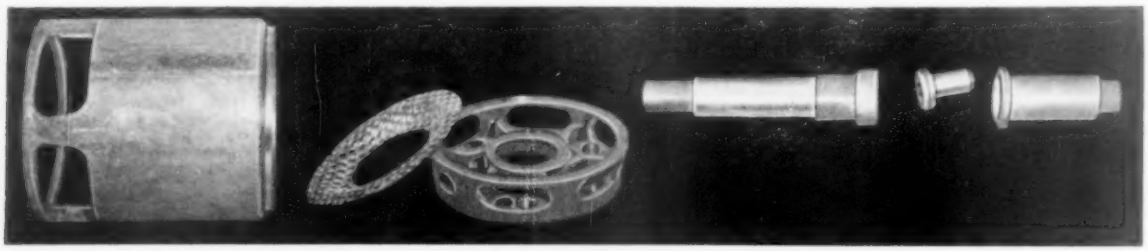


Fig. 1 These are six parts of an electric motor welded by the inert-gas metal-arc process. The three pieces on the left comprise the motor frame, while the three on the right constitute the armature shaft

SOMETHING'S UP... WITH INERT-GAS-SHIELDED METAL-ARC WELDING

When a modern airliner takes to the sky, inert-gas metal-arc-welded electric motors raise the landing gear to streamline the plane for flight. To meet today's aviation demands for these valuable electric motors, this mechanized process was called on to boost production at Red Bank Division of Bendix Aviation Corp. *Results: a 25% production increase at a lower cost per unit* compared to the submerged-arc welding process used previously.

Both the motor frame and the armature shaft of the electric motors are inert-gas metal-arc welded to provide the strong, dependable joints necessary to withstand extreme operating conditions.

The three pieces of the armature shaft are first pressed together in a hand-operated arbor press and then inert-gas metal-arc welded on a lathe-type fixture. The three pieces of the motor frame—screening, yoke and head assembly—are hand-assembled, aligned on the armature shaft which is still in the welding fixture and joined by inert-gas metal-arc welding.

A $\frac{3}{32}$-in. diam wire provides the filler metal, and an argon-oxygen gas mixture blankets the weld area—stabilizing the arc and producing a well-shaped weld bead.

Based upon a story by Linde Co., New York, N. Y.

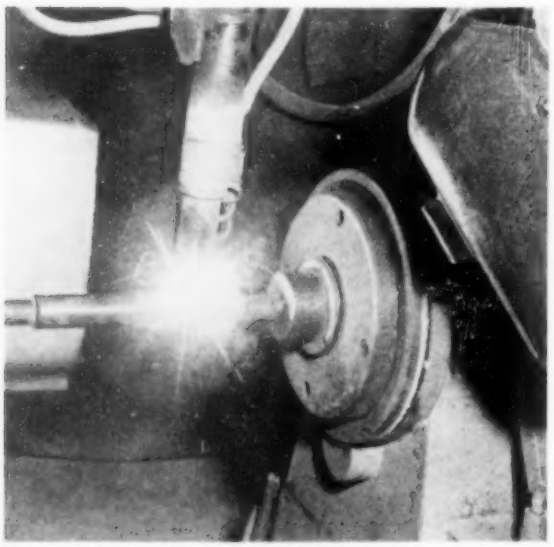


Fig. 2 After the three pieces of the armature shaft have been assembled in a hand arbor press, they are joined by automatic inert-gas metal-arc welding in a lathe-type fixture

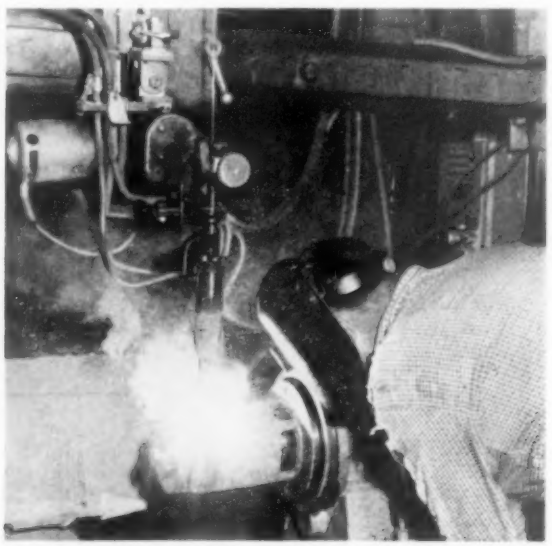


Fig. 3 With the motor-frame parts temporarily assembled on the armature shaft, the parts are welded with an inert-gas metal-arc torch

Fig. 1 Connecticut Turnpike's Yankee Doodle Bridge, crossing the Norwalk River at Norwalk, Conn.

NEW TURNPIKE BRIDGES ARE WELDED

The new Connecticut Turnpike's Yankee Doodle Bridge, crossing the Norwalk River at Norwalk, Conn., is an all-welded bridge (Fig. 1). Its seven spans make a total length of 940 ft. The Turnpike has 28 all-welded bridges, the largest of which is the 24-span, 2661-ft Mianus River Bridge at Greenwich. The smallest is the single span of 103 ft over Route 161 at East Lyme. Most of the bridges are two- or three-span road crossings between 175 and 225 ft long. The Turnpike's welded bridges are among the country's longest welded-plate girder bridges. They are the latest built in Connecticut's long history of using welded construction, dating back over 20 years. Welded rigid-frame bridges were used on the Merritt Parkway in 1938, one of the country's first superhighways. The example, given by the experience of such states as Connecticut, and others such as New York, Texas, California and Kansas, has shown that savings ranging from 10 to 20% are possible in efficiently designed welded bridges.

Based on a story by The Lincoln Electric Co., Cleveland, Ohio.

SUBMERGED-ARC WELDING T-1 STEEL IN BIG FABRICATED BEAMS

Fig. 1 Depositing fillet weld with portable semiautomatic welder

Portable semiautomatic welder makes long fillet welds on double-beveled Tee joints (Fig. 1). Welder cone rides a specially rigged cutting buggy. A heating torch precedes the welder and preheats the joint to about 200° F. A flux recovery unit follows the welder and collects excess flux that is not consumed in welding. Specially compounded alloy flux, used with mild-steel electrode, produces weld metal with properties similar to those of the T-1 steel base metal. Five passes made at speeds of 10–14 ipm were required to fill each side of the joint. The large girders have 1 1/4-in. thick webs and 2-in. thick flanges. They were fabricated for the John F. Beasley Construction Co. of Dallas, Muskogee and Chicago. Eighty feet long when completed, the girders are the main member of the base of a large portable derrick.

Based on a story by The Lincoln Electric Co., Cleveland, Ohio.

Society News

Maintenance and Hard-Surfacing Award Sponsored by Davis

A new yearly award for the best contribution in the field of maintenance and hard surfacing has been announced by the AMERICAN WELDING SOCIETY. This is the third award made possible by its donor, A. F. Davis, vice-president and secretary of the Lincoln Electric Co., Cleveland, Ohio.

The Davis silver medal and certificate will be awarded annually to each author of the paper selected by the AWS Committee on Awards as the best paper published in THE WELDING JOURNAL on maintenance and hard surfacing. To qualify for the award, the paper may be written by one or two authors and published in THE WELDING JOURNAL during the 12-month period ending with the December issue. The initial award period covers the 1958 calendar year.

The first two awards, established a year ago, cover the fields of structural and machine design and consist of a silver medal and certificate similar to the newly established award on maintenance and hard surfacing. All three awards will be presented during the 40th AWS Annual Convention in April 1959, at Chicago, Ill.

LAST CALL FOR AUTHORS!

Abstracts of proposed papers for AWS 40th Annual Meeting must reach AWS headquarters not later than

August 15, 1958

Send yours in *NOW!*

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Pandjiris Enrolled as Sustaining Member

The Pandjiris Weldment Co., St. Louis 10, Mo., has obtained sustaining membership status in the AMERICAN WELDING SOCIETY. The firm offers complete engineering and manufacturing services with integrated facilities in space covering 50,000 sq ft.

Their work is devoted exclusively to designing, building and testing of automatic welding devices augmenting high-speed automatic arc-welding heads and power sources presently available on the market.

Pandjiris' production is classified into three categories:

1. Standard cantilevered type positioners, turning rolls, head and tailstocks, boom-type manipulators and internal and external mandrel-type seamers.
2. "Auto-Weld-Matons" which include custom-built machines for specific applications or a series of welding sequences.
3. Research and development on customer's products and their own processes.

Through foresight and the strong belief in the future of automatic welding, the Pandjiris Weldment Co. was organized by "Nip" Pandjiris in June of 1946.

Sustaining Member representative is A. K. Pandjiris.

THINGS YOU SHOULD KNOW

(That Happened in the 1957–58 Fiscal Year)

The following is quoted from the annual report of your Secretary covering the 1957–58 fiscal year which ended May 31, 1958.

As a result of the outstanding leadership of our National, District and Section Officers, and of our Committee Chairmen and Members, together with the effective service of the SOCIETY staff, the SOCIETY has continued to expand its activities and yet operate within the budget established by the Finance and Executive Committees and approved by the Board of Directors at the beginning of the fiscal year.

● *Our President:* The SOCIETY has been exceptionally fortunate in the guidance and leadership furnished by a President who has a long history of SOCIETY activity and has for the past 30 years served in industry as a top executive directly concerned with the production and construction of metal assemblies. During his term as President of our SOCIETY, he has given generously of his time and traveled extensively, covering all sections of the country and visiting many groups, frequently with your Secretary. He opened his term without the services of two top staff members who had resigned. A business recession, combined with advances in membership dues and the requiring of initiation and reinstatement fees, created difficulties in expanding or even maintaining membership. With characteristic diplomacy and quiet efficiency, he has solved these and other problems efficiently and effectively. He has spoken to many Sections and other groups outlining SOCIETY activities and objectives, and stressing the importance and advantages of participation in SOCIETY affairs. The SOCIETY is greatly indebted to President C. P. Sauder, and to his company, for his outstanding contributions to AWS.

● *Our Prime Officers:* President-Elect G. O. Hoglund is very well known for his participation in AWS affairs and for committee and technical activities in other societies. This year he has served as First Vice President, Chairman of the Technical Council, the AWS-CWS Liaison Committee and the Task Committee for AWS 1959 Fall Meeting and as Member of the Board of Directors and its Executive and Finance Committees. He has also served on several other standing, special and technical committees. In 1939 Mr. Hoglund was awarded the Lincoln Gold Medal.

First Vice President-Elect C. L. MacGuffie is another long-time active member of the AWS who has been associated with the welding industry for many years. He has served the SOCIETY as Chairman of the Philadelphia Section and in many other capacities, including, during the past year, the chairmanship of the Reserve Funds and Welding Information Committees and membership on the Board of Directors and its Executive and Finance Committees, and on the Technical Council, Headquarters Housing, Manufacturers and other committees.

Second Vice President-Elect R. D. Thomas, Jr., is a Past Chairman of the Philadelphia Section and has served on many technical committees of the AWS and other societies. He has presented technical papers before local, national and international groups and has taught various courses at Temple University and Drexel Institute of Technology.

These three prime officers provide a wealth of industrial, technical and executive talent and experience which will insure a continuing high-level leadership for the SOCIETY.

● *Our Junior Past Presidents:* Our two Junior Past Presidents, J. J. Clyle and J. H. Humberstone, have continued their keen interest and active participation in SOCIETY activities. Mr. Humberstone has served as Member of the Board of Directors and its Executive and Finance Committees, as Chairman of the important Headquarters Housing Committee and as Member of the Manufacturers, Honorary Membership, National Nominating, Reserve Funds and other standing and special committees. Mr. Clyle has served as Chairman of the Sustaining Membership Committee, continuing the campaign initiated last year with outstanding success. He has also been Chairman of the Honorary Membership and Past Presidents Committees, and a Member of the Board of Directors, the Educational Activities, the WELDING HANDBOOK and the Organization Structure Committees and has represented the SOCIETY on the National Research Council and the Governing Council of the International Institute of Welding. The assistance of these and other Past Presidents has contributed significantly in achieving some of the outstanding accomplishments of the past year.

● *Our Treasurer:* H. E. Rockefeller has completed the first year of a three-year term as Treasurer of the SOCIETY, serving also as a Member of the Board of Directors and its Executive Committee, Chairman of its Finance Committee and a Member of the Convention, Headquarters Housing, Exposition, Reserve Funds and Organization Structure Committees. Under his leadership a balanced budget amounting to $551,771 of income and expenses for the 1957–58 fiscal year was prepared in a new format designed to clearly show the income and expense which should be credited or charged to each of the major activities of the SOCIETY. THE SOCIETY has operated successfully under this budget and completed the fiscal year with an excess of income over expense of more than $10,000. Sales of the first section of the Fourth Edition of the WELDING HANDBOOK and of certain technical publications have exceeded budget estimates and more than offset minor deficits in budgeted income from other sources. Total expenses were essentially equal to budget predictions.

● *Board of Directors:* The Board of Directors consists of the President, the two Vice Presidents, the Treasurer, the three Junior Past Presidents, twelve Directors-at-Large and eleven District Directors. Dr. Comfort A. Adams, Founder and First President of the SOCIETY, served as Honorary Director until his death on Feb. 21, 1958. The Board of Directors delegates power to its Executive Committee to act between Board meetings. The Technical Council is a Committee of Board Members given power to act for the Board on technical matters. The Finance Committee also consists of Members of the Board of Directors. The men forming these groups are responsible for determining all major policies for the SOCIETY. They are leaders in commerce, industry and professional fields who use their time and talents in studying SOCIETY problems and approving proper actions to be taken regarding them.

● *Section Officers:* Several hundred members serve as officers and committee chairmen in charge of the activities of our Sections. These men who have direct contact with AWS members on the local level provide the motivation, the ideas, the inspiration and the direction which determine the success of their Section and collectively that of the entire SOCIETY. We are greatly indebted to these men.

● *Committee Members:* Thousands of man-hours are devoted to the diversified activities of the operating and technical committees of our SOCIETY. The reports of Committee Chairmen outline but cannot give a complete statement of these activities. Literally hundreds of

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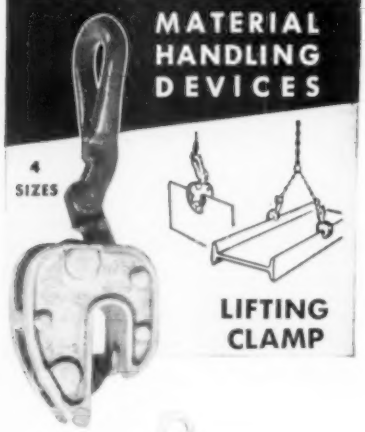

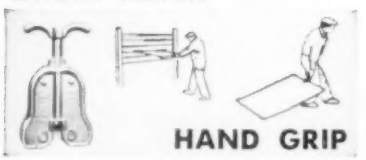

For Interesting Information write

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different individuals contribute their time, knowledge and experience in helping their fellow members and others meet the ever expanding challenges in the fields of welded construction. In these fine cooperative efforts lies one of the great strengths and opportunities for service of our SOCIETY. To these men we also owe a great debt.

● *Staff:* The following is an alphabetical list of a few of the staff members together with the major activities for which they are responsible: E. A. Fenton, Technical Activities; E. Krisman, Membership Activities; F. J. Mooney, Convention, Office, Financial Activities; A. L. Phillips, HANDBOOK, Educational, Information Activities; B. E. Rossi, WELDING JOURNAL and Technical Papers Committee Activities. R. T. Kenworthy is employed as Exposition Manager.

These men and the other staff members are directly responsible for executing the plans and policies determined by the Board of Directors. They have given your Secretary excellent support, cooperating fully and serving the SOCIETY loyally and effectively.

● *Society Highlights:* The Technical Department has issued nine major publications including the popular comparison charts for electrodes, welding bibliographies, an X-ray standard for aluminum, nondestructive test symbols, two safety standards and three electrode specifications. It is expected that 15 more publications may be issued next year including a Soldering Manual, specifications covering Welded Bridges, Welded Buildings, Welded Reinforcing Steel, Nuclear Power Piping, Titanium Piping and a revised set of Welding Symbols.

The demand for and approval of the first section of the Fourth Edition of the WELDING HANDBOOK has been most gratifying. The preparation of the second section is well advanced and committees are being formed for the third section which will be issued in 1959.

THE WELDING JOURNAL has introduced new features which have increased reader interest and which yield greater values to advertisers. A recent survey has demonstrated the exceptionally effective coverage the JOURNAL provides to its advertisers.

● Through the generosity of A. F. Davis two new awards consisting of a Silver medal and a certificate are now available to members who submit the best papers published each calendar year in THE WELDING JOURNAL in the fields of Machine Design and Structural Design. The Awards Committee now operates with a number of subcommittees, each handling one of the several honors awarded each year.

● During the past few years, an Organization Structure Committee has been developing recommendations covering officers and councils or boards which might most effectively serve the SOCIETY as it continues to grow and expand its activities. The Constitution and By-Laws Committee prepared suggested by-laws giving effect to these recommendations which have been approved by the Board of Directors. These suggested by-laws were approved by the Board of Directors at their meeting held Apr. 17, 1958.

● The Annual Spring Meeting of the SOCIETY which was held in St. Louis, Apr. 14 to 18, 1958, was one of the most outstanding with 63 technical papers, a series of educational lectures, an educational conference, two plant tours, the President's Reception, the Annual Banquet and meetings of the Board of Directors, Technical Council and many Standing and Technical Committees and other groups such as Sustaining Members, RWMA, WRC, PVRC and similar associated activities including the ASME which cosponsored some of the technical sessions.

● The 6th Welding Exposition held during the same period in Kiel Auditorium in St. Louis was equal in area to the record-breaking exposition which was held in Philadelphia last year.

● The Board of Directors has tentatively approved the recommendation of the Headquarters Housing Committee to accept the invitation of the United Engineering Trustees to establish SOCIETY headquarters in the New Engineering Center to be erected near the United Nations Building in New York.

● During the past two years, the Manufacturers' Committee and the Welding Information Committee have considered the development of an effective information program for the SOCIETY and the establishment of an Information Center at SOCIETY headquarters. A suggested program was outlined and industry was contacted in an effort to raise a fund of $60,000 with which to initiate the program. Although representatives of the manufacturers and distributors generally favored the program, the total amount was not subscribed and it was decided to substitute a program to be handled by staff members, with the cost included in the SOCIETY budget. Definite recommendations covering duties of staff members assigned to this activity were prepared by the Welding Information Committee and submitted to the Board of Directors at their Apr. 17, 1958 meeting. It is expected that this new activity may be started soon after June 1, 1958.

● A number of educational books and manuals has been given to the SOCIETY or prepared by committees and staff members of the SOCIETY. These include four books on arc and gas weld-

No rewelding possible...

Job for Inco-Weld "A"... the electrode that handles most problem joints...

and welds most dissimilar alloys, too

This weldor is fabricating a 12-foot high stainless steel reaction vessel designed to operate at more than 1200°F.

Insulating jacket prevents weld repairs...

In service, this vessel is entirely covered by an insulating jacket. Permanent welds are a must to prevent lengthy delays for repairs.

The root pass was made with a stainless steel electrode matching that of the vessel. But then the problem started. Toronto Coppersmithing engineers wanted to avoid heat treating the vessel after welding to remove weld brittleness. The welds had to be strong enough to withstand 1200°F. and be unusually ductile.

Inco-Weld "A" Electrode produces strong, sound, ductile welds

After a series of tests, they found Inco-Weld "A"* Electrode could be depended upon to produce the high quality welds needed without special procedures. What's more, the deposits made with this electrode have a coefficient of expansion close to that of the stainless steel – an important advantage when operating temperatures soar to 1200°F!

What's your joining problem?

Try a few tests with versatile Inco-Weld "A"† Electrode, the electrode with the distinctive green flux, for welding dissimilar alloy combinations, or Inco-Weld "A" Wire – the new inert-gas metal-arc wire just introduced. Both produce high quality welds between ferritic and austenitic stainless steel, low alloy and mild steel, high nickel and other alloys.

Get this new booklet

"Now You Can Weld Dissimilar Alloys Easily" includes case histories on problem welds solved and results on test data compiled on dissimilar alloy combinations. Send for your copy.

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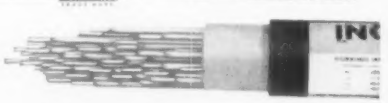

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ing presented by the Air Reduction Sales Co., a training manual presented by the International Acetylene Assn., a new manual of arc welding, and chapters on arc welding and welded joints, suitable for inclusion in college textbooks, which are being prepared for NEMA and may be offered to AWS for distribution.

● New and expanded "Speakers Directory" and "Film Directory" have been prepared. Other publications including course outlines and complete courses are being prepared by Educational Committee dealing with In-Plant Training, College Training, Apprentice Training, Extension Training, Visual Aids and AWS Section Courses covering welding metallurgy, thermal cutting of metals, resistance welding, welding design, weldability of metals, automatic and semiautomatic welding and similar subjects.

● The Reserve Funds Committee has prepared important recommendations, recently approved by the Board of Directors, establishing a goal of $400,000 for this fund, combining other existing contingent funds with the reserve fund, stating objectives of the fund and outlining rules covering contributions to the fund and use of income earned by the fund.

● The SOCIETY has continued its participation in activities of the International Institute of Welding. The Board of Directors has voted to have the SOCIETY Secretary assume the duties of the American Secretariat of IIW about Jan. 1, 1959.

● During the year a special AWS-CWS Liaison Committee has continued conversations with representatives of the Canadian Welding Society concerning closer cooperation of the two societies and the possible use by the CWS of AWS WELDING JOURNAL, HANDBOOK and other technical publications.

● The SOCIETY has received and acted on a request to form a special advisory committee which might be consulted concerning welding problems by groups associated with the Atomic Energy Commission.

● Your Secretary has attended meetings of 45 Sections, Divisions and District Conferences during the 1957-58 fiscal year. He spoke at all of these meetings, presenting the principal technical or semitechnical discussion on most occasions. In addition he attended meetings of associated groups such as IAA, NEMA, NWSA, ASM, API, NFPA, ASA, WRC, IIW, ASCE and PVRC, of which he is National Chairman. He of course attends all meetings of the Board of Directors, Executive and Finance Committees, Technical Council, Convention, Headquarters Housing, Manufacturers, Exposition, Welding Information, Organization Structure and many other operating and technical committees.

● During the 1957-58 fiscal year your Secretary has attempted to keep members better informed about SOCIETY activities by preparing a section "Things You Should Know" which is published each month in THE WELDING JOURNAL. He has also mailed informal memorandums about staff and committee activities to members of the Board of Directors in order to keep them informed of developments occurring in intervals between meetings of the Board.

Fred L. Plummer

AUGUST 15, 1958

is

DEADLINE

for Abstracts of Papers Proposed for

AWS 40th Annual Meeting

ACT NOW!

Sustaining Membership for RWMA

The Resistance Welder Manufacturers' Association, 1900 Arch St., Philadelphia 3, Pa., has affiliated with the AMERICAN WELDING SOCIETY as a Sustaining Member.

RWMA is comprised of fifteen manufacturers of resistance-welding machines and equipment. The association engages in research, educational and promotional activities. Standards and specifications are developed by the Technical Committee, assisted and advised by Subcommittees. The Association has published a Resistance Welding Manual and numerous technical bulletins. It has recently produced its first film, a 16-mm color and sound movie featuring resistance-welding applications.

The Sustaining Member representative is R. Bruce Wall, secretary-treasurer.

New Supporting Company from West Coast

The following firm, Long Beach Welders Supply Inc., 1629 W. Anaheim St., Long Beach 13, Calif., is now a Supporting Company member of the AMERICAN WELDING SOCIETY. Enrollment became effective as of May 1, 1958.

AWS COMMITTEE TOURS OAK RIDGE LABORATORY

Following their Gatlinburg, Tenn., conference, members of the AWS Committee on Piping and Tubing were guests of Union Carbide Corp. for a tour of nuclear facilities at Oak Ridge National Laboratory. Here, the welding experts are viewing the loading face of the graphite reactor which is the world's oldest operating reactor. Much of the world's supply of radioisotopes are made at Oak Ridge National Laboratory

EDUCATIONAL ACTIVITIES

A Report on Welding Education in Europe

by Clarence E. Jackson

C. E. Jackson

As I write this message, it has been just a month since I returned to the States after having spent the spring months in England and on the Continent. The special assignment abroad provided an unusual opportunity of trying to be a good American in friendly countries; it was not unexpected to learn that the basic psychological goals of many free people are similar to our own. The mature adult in the free world wants desperately to understand, know and contribute a bit to what he honestly feels is a better world for himself, his associates and those who have a fundamental philosophy congruent with his training and livelihood. Technically, the engineers of each country recognize their own problems and sometimes forget that other engineers are also pestered by special specifications, unreasonable codes, special service requirements, frustrating controls and "enlightened" competition. International cooperation and increased emphasis on education will result in better understanding and improved associations. The question which confronts those of us interested in education is one of directing our effort toward gaining the most satisfactory and the quickest returns from the effort being expended. Each of us in our own special dedicated field hopes and knows that education is one of the important keys in the final solution of problems, whether they have their origin in differences among races, people, nations or, in a more limited sense, among individuals, tradesmen, teachers, scientists or engineers.

It is gratifying to note that in the United States as in Europe there has been an increased interest in education. Almost every magazine presents special reports aimed at clarifying the needs of our educational system. *Business Week* (April 14, 1958) states that in terms of number of children in school, literacy rates in the population, average educational level, college degrees, number of schools per capita, the United States has nothing to worry about. But the paradox of dealing with the whole range of student abilities and yet remaining classless, coeducational, nonpartisan and secular is still unresolved. The United States is committed to the idea that it can profitably give 12 years of education to everyone. Comparisons with Britain or Russia drive home the point that United States education on the whole has been doing too little with its most able students. People everywhere are turning to the many facets of education.

The program and development of the International Institute of Welding will be of much guidance in our future activities. For example, Commission XIV, "Welding Instruction," of the IIW makes the following statement: "A welding engineer must be first and foremost a qualified engineer who by theoretical and practical studies has acquired knowledge and experience on matters concerned with welding and its applications. In all cases which involve welding, the welding engineer of an industrial organization must have been trained to act as liaison officer and responsible consultant to the people concerned with design, procedure, planning, inspection and testing and plant maintenance."

The specific job of a welding engineer may vary from country to country, but the general duties of the job are similar. In Great Britain the welding engineer is not necessarily a specialist in welding but may be an engineer who has later specialized in welding. In addition, practical welding engineers are drawn from those who have served an apprenticeship, received the necessary technical education and have afterwards specialized in welding. The applicants for membership in the British Institute of Welding must pass the corresponding examination if they have not graduated from a university or cannot present similar certificates or memberships. After looking over a copy of past examinations which Mr. G. M. Boyd at the BIW gave me, I can vouch for the thoroughness of the coverage of the examination; it is refreshing and inspiring to note the professional trend.

In Germany the term *welding engineer* covers nearly exclusively the "welding specialist" with an acquired knowledge of official regulations of the Training and Testing Institute of Welding (Schweisstechnische Lehr-und-Versuchsanstalten). In most operations this special engineer is responsible for all welded work. In some cases the welding specialist's field of activity covers only the welding shop. In others the design of welded workpieces and structures is also included. Sometimes no drawing of a weldment is passed on to the shop until the welding engineer has signed it, thus himself assuming the responsibility. His duties are therefore many sided.

In France few official regulations are applicable, and any engineer who is familiar with welding and interested in it can call himself a "welding engineer." The school system, especially the French Institute of Welding (Institute de Soudure), provides extensive instruction facilities. We find the situation in France quite similar to that in the United States, where the welding engineer may be an individual fully trained academically, educated in a special field of study, or a man of practical experience who has worked his way up in the firm by his own abilities.

In the United States a precise definition of the term *welding engineer* is difficult. It is evident that this term is applied to an engineer who devotes the better part of his time to welding problems.

Increasing cooperation between our committees and those of the International Institute of Welding and associated groups can result in faster progress and a sounder program for the promotion of our educational aims.

Clarence E. Jackson is Chairman of the Educational Activities Committee of AWS and is research metallurgist with the Linde Development Laboratory, Newark, N. J.

Section News and Events

as reported to Catherine O'Leary

California

ANNUAL WELDERS BALL

Long Beach, Calif.—The Annual Welders Ball was held on May 16th at the Lafayette Hotel in Long Beach. This is an annual affair of the *Long Beach* Section in which members, wives and guests enjoy an evening of dining and dancing. Music was furnished by The Townsmen.

ACHIEVEMENT AWARDS

Long Beach, Calif.—For the fifth straight year, the *Long Beach* Section presented trophies to the Junior Colleges and cash awards to the students showing outstanding ability in their chosen fields of welding.

This year, Gerald Garfield, chairman Achievement Awards, and his committee, selected El Camino College to receive the trophy for oxyacetylene welding. The individual winner of the cash award was Andrew G. Presley, Jr.

Trophies for arc welding and combination arc-gas were awarded to the Long Beach City College. Winners of the awards were R. E. Glick, arc welding, and R. G. Morales, combination arc and gas.

In memory of H. I. Tullis, who was a charter and sustaining member of the Long Beach Section, Mrs. Mary Tullis created the H. I. Tullis Memorial Foundation and placed in trust with the Section $1000 to be awarded to the most outstanding student of a junior college. This award amounts to $100 and is in addition to any other awards that may be given.

This year this award was given to Jess Rankin who was outstanding in all phases of welding.

WELDING IN THE AIRCRAFT INDUSTRY

Long Beach, Calif. The *Long Beach* Section held its June 20th technical meeting at Alfred's Restaurant.

Charles B. Smith, junior past chairman of the Los Angeles Section and past national membership chairman, was the guest speaker. He selected as his subject past and present aircraft manufactured by his company, Douglas Aircraft. His topic, of course, was welding and in discussing this he pointed out acceptable methods in the early days as compared with today. His subject was supported

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LONG BEACH SECTION HOLDS ANNUAL WELDERS' BALL

Past-Chairman A. J. Smoke and his party enjoying an evening of dining and dancing at the Annual Ball sponsored by the Long Beach Section on May 16th

Chairman Davenport (*right*) assisted by "Doc" Bowers and the talented lady of the accordion draw the lucky numbers for door prizes

Among the many familiar faces seen at this gala affair were (*left to right*) Messrs. Cox, Graham, Davenport, Teeter, Anderson and guest

SMITH DISCUSSES PAST AND PRESENT AIRCRAFT

Charles B. Smith was the principal speaker at the June 20th meeting of Long Beach Section. His subject dealt with past and present aircraft manufactured by Douglas Aircraft Co.

The coffee speaker, a skin-diving instructor from Los Angeles county, discussed his specialty and gear used

with slides showing early models of the aircraft manufactured and brought up to date with the current DC-8 jet liner.

The coffee speaker was an instructor from Los Angeles County and employee of Underwater Sports Shop of Napels, Calif. He displayed the necessary gear for skin diving and spear fishing, and gave a very educational talk on the safety practices recommended in using the equipment.

A color film, "The Other End of the Line," was shown.

WELDING INCONEL X

Huntington Park, Calif.—Approximately 78 members and guests of the *Aircraft and Rocketry Panel, Los Angeles* Section, gathered together on Thursday, June 5th, at the Elks Club in Huntington Park to enjoy cocktails, dinner and an excellent paper on the welding and fabrication of Inconel X presented by Russell Meredith [illegible], lead engineer of welding and fabrication for the Missile Division Laboratory of North American Aviation Co.

Mr. Meredith's paper proved to be not only a very interesting one but quite timely, as considerable technical data are now being researched for alloys that will satisfactorily perform at elevated temperatures. The paper was well supported with slides and was followed by an extensive discussion period.

This was followed by the showing of a film in color, "Road to the Stars," shown through the courtesy of Rocketdyne, Missile Division of North American Aviation.

ANNUAL ELECTION

Sunnyvale, Calif.—A dinner was held at Jamaica Inn, Sunnyvale, Calif., on June 7th for members of the *Santa Clara Valley* Section. New officers for the fiscal year were presented as follows by the retiring chairman, M. J. Sebastian: Chairman, A. M. Hubbard, Pittsburgh-Des Moines Steel Co.; 1st Vice Chairman, R. N. Skow, Linde Co.; 2nd Vice Chairman, W. R. Smith, General Electric Co.; Secretary, F. D. Nelson, Food Machinery & Chemical Corp., Canning Machinery Division; Treasurer, V. S. Zacharenko, Westinghouse Electric Corp.; Executive Committee, Richard Bedding, Robert Bertossa, Donald Carlson, D. R. Fylling, Joseph Garcia, V. L. Krankenberg, Lon Mayr, R. A. O'Neill, Arnold Otto, R. H. Sherman,

ACHIEVEMENT AWARDS MADE BY LONG BEACH SECTION

A. G. Presley, Jr. (*center*), of El Camino College, is the recipient of the trophy for oxyacetylene welding. Award Committee Chairman G. Garfield is at left, and Instructor G. Davis at right

R. E. Glick and R. G. Morales of Long Beach City College were awarded trophies for arc welding and combination arc-gas welding, respectively. The H. I. Tullis Memorial Foundation award of $100 went to Jess Rankin. Left to right (*above*) are Mr. Glick, Jim Creig (instructor), Mr. Morales and Mr. Rankin

MEREDITH SPEAKS ON WELDING OF INCONEL X

Some of the many Aircraft and Rocketry Panel members and guests who turned out for the June 5th meeting in Huntington Park

Technical Speaker Russell Meredith presenting his paper on "Design and Fabrication of an Inconel X Missile Rudder Shaft"

M. D. Bellware, a guest from the New York Section, participating in the discussion of Mr. Meredith's paper

1958
Educational Lecture Series

Sponsored by
Chicago Section
Sept. 4, 11, 18, 25, Oct. 2, 1958

Practical Welding Metallurgy
By Jay Bland
Standard Oil Co. (Ind.)

STEEL MAKING PROCESSES Types of steel Mechanical properties	*Thursday, September 4*
WELDING PROCESSES Introduction to metallurgy Simple welds in steel	*Thursday, September 11*
THERMAL EFFECTS OF WELDING Base metal factors Tests to measure weldability	*Thursday, September 18*
FLUXES AND SLAGS Electrode classifications	*Thursday, September 25*
DIFFICULTIES AND DEFECTS Welding common steels Welding economies	*Thursday, October 2*

TEXT: *Welding Metallurgy* by Henry & Claussen

PLACE: Chicago Bridge and Iron Co. Dome
1305 W. 105th St., Chicago, Ill.

MEETING TIME: 7-9 P.M.

REGISTRATION FEE: Members $10
Nonmembers $12
(includes text)

Contact R. C. Becker, Chairman Chicago Educational Activities Committee, c/o International Harvester Co., 5220 S. Western Ave., Chicago 9, Ill.

John Weyers and R. W. Woodling.

Colorado

NONTECHNICAL MEETING

Denver, Colo.—The *Colorado* Section held its final meeting of the season on June 10th at the El Rio Grande Cafeteria in Denver. A social half hour and dinner preceded the meeting.

After dinner, the group was treated to a talk by Terry Rand of the Denver-Chicago Trucking Co. Mr. Rand is also the A.A.U. "All-America Center" of the D-C Truckers Basketball Team of Denver. His talk was accompanied by slides of colored pictures he took during the recently completed All-America team's series of six games in Russia. Mr. Rand's presentation was excellent and he proved himself capable of handling the conversational ball as well as the basketball.

Election of officers for 1958–59 was announced as follows: Chairman, C. E. Withers, USBR; 1st Vice Chairman, J. R. Mascarello, Allied Steel Co.; 2nd Vice Chairman, Paul J. Foehl, Midwest Steel & Iron Works; Secretary-Treasurer, Edmund J. Berens; Executive Committee, R. E. Scott, Edward O. Browning, E. W. Weinberger, D. C. Card, C. Brinton Swift, E. G. Watson and William H. Young.

NEW CHAIRMAN

A. M. Hubbard (*left*), the incoming chairman of the Santa Clara Valley Section, receives the symbolic gavel from the retiring chairman, M. J. Sebastian, at the June 7th meeting

Illinois

THE FUTURE OF WELDING

Chicago, Ill.—Ted B. Jefferson [M], editor and publisher of *Welding Engineer* and *The Welding Distributor*, was the guest speaker at the May 16th meeting of the *Chicago* Section held in the Auditorium of the Peoples Gas Lite & Coke Co.

CHICAGO SPEAKER

"The Future of Welding" was the subject of Ted Jefferson's talk before the Chicago Section on May 16th

Mr. Jefferson's talk concerned the future in welding, the lack of men in the field and the great need for good men in the future.

The film of last year's golf outing was of interest to all and many saw themselves play golf, and hope to be filmed again at this year's outing.

Louisiana

ELECTION OF OFFICERS

New Orleans, La.—An election meeting of the *New Orleans* Section was held on April 22nd at the Watkins Restaurant with 55 members and guests present.

Newly elected officers for 1958-59 were introduced as follows: Chairman, J. A. Wilson; Vice Chairman, W. G. Blackwell; Secretary, G. G. Haddock, Jr.; and Treasurer, S. L. Ritter.

Missouri

FBI WORK

Kansas City, Mo.—The final meeting of the *Kansas City* Section for the season was held on May 8th at the Golden Ox Restaurant in Kansas City.

A short Board of Directors' meeting was held prior to the principal meeting. The latter featured an address by W. Mark Felt of the Federal Bureau of Investigation on some phases of this work in the Kansas City area. Everyone seemed to enjoy this entertaining program.

New Jersey

ECONOMY OF WELDING

Newark, N. J.—One hundred and thirty members and guests of the *New Jersey* Section met on May 20th at the Essex House Hotel in Newark for the regular monthly meeting.

The evening's activities started with cocktails and dinner with 92 members and guests present, including national officers—President G. O. Hoglund, First Vice-President C. J.

NEW ORLEANS SECTION ELECTS OFFICERS

Recently elected officers of the New Orleans Section are, standing (*left to right*): W. A. Wilson, chairman; R. A. Flautt, Jr., outgoing chairman; G. G. Haddock, secretary; and S. L. Ritter, treasurer. Seated (*left to right*) are: W. G. Blackwell, vice chairman, and J. M. Bayhi, outgoing vice chairman

For details, circle No. 10 on Reader Information Card

HUMBERSTONE SPEAKS BEFORE NEW JERSEY SECTION

Past-President Joseph H. Humberstone was the principal speaker at the May 20th meeting of New Jersey Section. Topic: "Economic Advances of Welding of Interest to Top Management"

The newly elected officers of the New Jersey Section for the 1958–59 fiscal year are (*left to right*): H. W. Hoffman, vice chairman; S. L. Sullivan, treasurer; W. G. Benz, chairman; and R. V. Thornton, secretary

MacGutlie and National Secretary F. L. Plummer.

The Section officers for the 1958-59 season were introduced as follows: Chairman, W. G. Benz; Vice Chairman, H. L. Hoffman; Treasurer, S. L. Sullivan; and Secretary, R. V. Thornton.

J. H. Humberstone, president of Air Reduction Sales Co. and past AWS president, was the principal speaker for the evening. He chose as his subject, "Economic Advances of Welding of Interest to Top Management." Mr. Humberstone's opening remark drew his audience's immediate attention as it had reference to the possibility of welding the crack in the Liberty Bell at Independence Hall and precisely matching the composition of the base metal producing a homogeneous bond, whereby the bell would ring as true as it did in 1776.

Mr. Humberstone covered the application of welding in all phases of construction and manufacturing, from dish washers to guided missiles, pointing out that all metal-fabricating jobs should be analyzed in the light of modern welding techniques, the flexibility of welded design, how welding and castings complement each other and how the time element can be cut from the purchase of material to finished product.

Mr. Humberstone received a standing ovation and answered innumerable questions from his audience.

New York

OFFICERS AND COMMITTEES

New York, N. Y.—The following officers and committee chairmen for the *New York* Section have been elected as follows for the 1958-59 season: Chairman, G. Metterhauser, Air Reduction Sales Co.; 1st Vice Chairman, H. D. Landis, Jr., Armco International Corp.; 2nd Vice Chairman, G. H. Grunthaler, Jr., Midwest Piping and Supply Co., Inc.; Secretary, M. D. Bellware, International Nickel Co., Inc.; Treasurer, W. K. Honan, Handy and Harman; Program Committee, John L. Cahill, New York Naval Shipyard; Membership Committee, D. F. Little, Jr., Metal & Thermit Corp.; Publicity Committee, Anders V. Thoren, The Travelers Insurance Co.; Year Book Committee, W. Fitzgibbons, Air Reduction Sales Co.; Smoker Committee, J. T. Stewart, Whitehead Metal Products Co., Inc.; Attendance and Welcoming Committee, E. C. Madison, Prest-O-Sales & Service, Inc.; Welding Clinic and Awards Committee, Technical Representative and Education, J. E. Taylorson, Linde Co.; Welfare Committee, H. D. Landis, Jr., Armco International Corp.

ELECTION OF OFFICERS

Buffalo, N. Y.—The *Niagara Frontier* Section announces the election of the following new officers for the 1958-59 season: Chairman, Ralph V. Voigt; 1st Vice Chairman, John C. Kalnuzny; 2nd Vice Chairman, William L. Burch; and Reporter, James J. Russ.

WELDING ALUMINUM

Kenmore, N. Y.—Aluminum welding was discussed by F. R. Baysinger AWS at the May 22nd meeting of the *Niagara Frontier* Section. Mr. Baysinger is head of the Welding Branch, Department of Metallurgical Research of Kaiser Aluminum & Chemical Corp. He told the 74 members present about the three new gas-shielded consumable electrode techniques.

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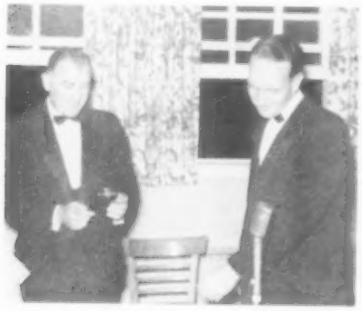
PHILADELPHIA SECTION HOLDS DINNER DANCE

Seated at the head table at the June 7th annual dinner dance of the Philadelphia Section are (*left to right*): Mrs. Carl M. Schaub, Chairman Schaub, Mrs. Byron Gates, Outgoing Chairman Byron Gates, Mrs. Frank Iapalucci, 1st Vice-Chairman Iapalucci



Chairman Schaub receives gavel from outgoing Chairman Gates

Fred Judelsohn leads community singing

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Mr. Baysinger pointed out that the two principal defects in aluminum welds are porosity, which is caused by hydrogen-containing contaminators such as water and oil, and dross (aluminum oxide) from oxygen contaminators such as water and entrained air. Most contaminators are on the wire and include drawing compounds, oil from shop atmosphere, moisture and oxides from caustic wire-cleaning processes. Makers now recognize the problem and offer spooled wire much cleaner than that of a few years ago.

The magnesium-aluminum wires are particularly prone to cause porosity when they are less than perfectly clean. The first process is intended for use with these wires and overcomes the hydrogen porosity by introducing an argon-3% chlorine mixture through the electrode contact tube. This is in addition to the usual 50 cfh argon in the gas nozzle. The second process is similar to the first except that the argon flow is reduced to 15 cfh to get economy with some loss in quality. Mr. Baysinger said these processes will not help with 4043 (5% silicon) wire.

The third technique is for economical noncode-quality welding of alloys other than Al-Mg. It uses 5 cfh argon in the contact tube and 15 cfh nitrogen in the gas nozzle and has shown a 34% reduction in welding costs per foot of weld over the conventional metal-arc inert-gas process.

North Carolina

WILDLIFE

Raleigh, N. C.—The regular meeting of the *Carolina* Section was held in the Colonial Room of the S. & W. Cafeteria in Raleigh on May 26th.

The results of election of officers for 1958-59 were announced as follows: Chairman, O. K. Barnes; 1st Vice Chairman, T. M. Jenkins; 2nd Vice Chairman, J. F. Knowles; Secretary, H. B. White; and Treasurer, R. Gussow.

No technical speaker was scheduled for this evening. Instead, W. L. Hammett, wildlife education representative for the North Carolina Wildlife Commission, gave a general talk on wildlife in North Carolina. He gave some very interesting statistics on hunting and fishing. The recommendations for changes in hunting and fishing rules to improve wildlife conditions in North Carolina were reviewed.

Ohio

RUTILE MINING OPERATIONS

Cincinnati, Ohio.—The *Cincinnati* Section met on May 27th at the Cincinnati Gas and Electric Co. and the Hartwell Country Club.

Speaker at the meeting was Edward A. Hobart [M] of Hobart Brothers Co., Troy, Ohio.

He gave a description of the mining operations in Florida for rutile and other minerals obtained from the sands on the Florida beaches and further inland. His talk was accompanied by a number of beautiful color slides showing the Florida scenery and various dredging and mining operations. His presentation was well received and stimulated a number of questions from the audience which were ably answered by the speaker.

Results of the election of officers were announced as follows: Chairman, R. M. Losee; 1st Vice Chairman, R. L. McKenney; 2nd Vice Chairman,

R. G. Gilliss; Secretary-Treasurer, M. A. Levinstein; Executive Committee, D. E. Hacker, G. S. Hoppin III and L. W. Mecklenborg.

ANNUAL PICNIC

Dayton, Ohio—Eighty-one members and guests of the *Dayton* Section attended the annual picnic held at the Inland Activities Center on Tuesday, June 3rd.

The picnic began at 5:30 P.M. with a program including games, dinner, dancing, refreshments and bingo.

The climax of the evening was the awarding of a past chairman's pin and certificate to retiring chairman Frank Gue.

Newly elected officers and members of the Board of Directors were announced as follows: Chairman, Dick Stratton; Vice Chairman, Tom Falter; Secretary, Bill Schober; and Treasurer, Clarence Schultheis.

Pennsylvania

ANNUAL DINNER MEETING

Erie, Pa.—The *Northwestern Pennsylvania* Section held its annual dinner meeting on Friday, May 23rd, at the Polish Falcons Club in Erie. The affair was attended by 42 members and their wives.

After the dinner, a color film entitled "Your Dreams Come True," which described new designs in kitchens, was shown.

Following the showing of the film, a bowling tournament was held in the club's bowling alleys. Prizes were given and a good time was had by all.

ANNUAL DINNER DANCE

Philadelphia, Pa.—The Germantown Cricket Club was once again the scene of the *Philadelphia* Section's annual social affair. Approximately 210 members attended this event on June 7th. The guests enjoyed cocktails on a second-story porch overlooking the very fine lawn-tennis courts of the club, which offers the most pleasurable surroundings and atmosphere.

A feature of the evening included community singing led by Section member Fred Judelsohn. A highlight of the evening was the presentation of a gavel to the incoming chairman, Carl Schaub, and past chairman's pin to retiring chairman, Byron Gates.

Each couple received a set of very attractive ash trays, and drawings were held for the distribution of very valuable door prizes.

These activities were followed by an evening of dancing and good fellowship.

Wisconsin

SPRING DINNER DANCE

Appleton, Wis.—On May 24th, the *Fox Valley* Section held its annual spring dinner dance. One hundred and forty-two men and their ladies enjoyed the delicious chicken dinner at the Appleton Elks Club, and then danced until 1:00 A.M. to the music of Cousin Fuzzy and His Cousins.

The hall was gaily decorated, and the ladies were presented with individual flowers. Beautiful flower center pieces on the dinner tables were given as door prizes.

The concensus of everyone present was that this was the most successful and enjoyable dinner dance in the history of the Section.

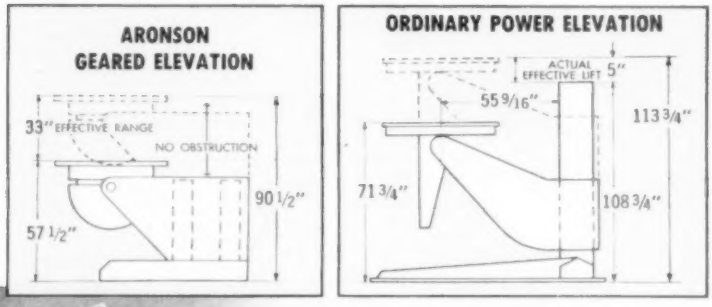
Ken Ligare was presented with a past-chairman pin and was applauded for serving the Section so ably during the past few years.

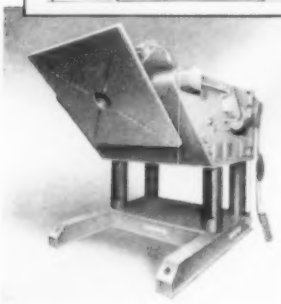
The new officers, led by John Wiegand, chairman, were introduced.

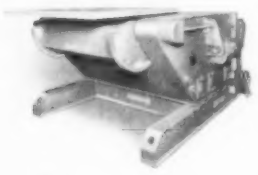
EDITOR'S NOTE: Notices for November 1958 meetings must reach Journal office prior to August 20, so that they may be published in October Calendar. Give full information concerning time, place, topic and speaker for each meeting.

Aronson GEARED ELEVATION Versus Ordinary Power Elevation

The best working position is as near the floor as possible. The only reason to elevate the work on the positioner is to give floor clearance for extra large work pieces.







In the ordinary positioner the workpiece can be no bigger than 9'-3" in diameter if it is to clear the single post sticking up the back.
This means that the single-post design requires large work to be loaded on the table in the flat position when the table is at least 108 ¾" (over NINE FEET high!) above the floor.
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MEMBERSHIP CLASSIFICATION

A—Sustaining Member B—Member C—Associate Member

D—Student Member E—Honorary Member F—Life Member

Total National Membership

Sustaining Members	*184*
Members	*6,120*
Associate Members	*5,887*
Student Members	*210*
Honorary Members	*9*
Life Members	*15*
Total	*12,425*

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ALBUQUERQUE

Page, L. A. (C)

BIRMINGHAM

Tidwell, Clyde (B)

BOSTON

Jones, Clark F. (C)
Quint, Harland J. (B)
Rose, Barnard A. (C)

CANADA

Miller, Ken F. (C)

CHATTANOOGA

McWaters, William J. (C)

CHICAGO

Figliozzi, John J. (B)
Johnston, James C. (B)
Moyer, Thomas J. (B)
Rouison, Henry E. (B)
Walls, Raymond Edward (B)
Wulfekuhle, Donald (B)

CINCINNATI

Witte, Charles William (C)

CLEVELAND

Havener, L. N. (C)
Symns, Samuel Y. (B)

COLORADO

Bayuk, Joseph M. (B)
Thompson, William L. (B)
Ward, Damon R. (B)

DALLAS

Ernst, Emery Leroy (B)

DAYTON

Moran, Robert Glen (C)

DETROIT

Antos, John (B)
Betts, William A. (B)
Crysler, Heath Leo (B)
Denton, Leslie B. (B)
De Santis, Daniel (C)
Kryszak, Steve (C)
Orman, Robert Kent (B)
Storch, Edward A. (B)
Webster, William Cooke (C)

HARTFORD

Matyschsyk, Leo R. (B)
Neumeister, Robert (C)

HOUSTON

Finley, Timothy F. (C)
Nevle, L. J. (B)

INDIANA

Neal, Ford D. (B)

LONG BEACH

Graham, Weldon (B)

LONG ISLAND

Apostal, Theodore C. (C)
Esgro, Angelo J. (C)
Galagaran, Robert (C)
Goebel, Robert E. (A)

LOS ANGELES

Cook, Robert Earl (B)
Frederickson, Lloyd W. (B)
Hinton, Ray F. (D)
Powers, Joseph E. (D)
Rittenhouse, William D. (D)

MILWAUKEE

Bote, Frederick C. (B)

NASHVILLE

Betty, H. B. (B)
Bevill, John L. (B)
Brach, Ernest J. W. (B)
Crecelius, Buford (B)
Cron, James E. (B)
Dotts, Stephen (B)
Elliott, Carney H. (B)
Elrod, Perry (B)
Goff, Paul W. (B)
Haworth, Burton C. (B)
Justice, John G. (B)
Krist, Stephen N. (B)
Langford, C. W. (B)
Mallory, James B. (B)
Martin, James W. Sr. (B)
Morgan, L. L. (C)
Raby, Joe B. (C)
Turner, Colie (C)
White, A. V. (B)

NEBRASKA

Thompson, Merle D. (D)

NEW JERSEY

Ahrens, Dagny A., Mrs. (A)
Poulos, Anthony J. (B)

NEW ORLEANS

Bonneval, Monty E. (B)

NEW YORK

Horton, Bradford L. (C)
Misiti, Monte (C)
Neilson, David H. (B)
Warren, Robert H. (B)

NORTHEAST TENNESSEE

Long, Laurence M. (C)

NORTHERN NEW YORK

Paez, Jose Miguel (C)

NORTHWEST

Cherne, A. W. (B)

NORTHWESTERN PA.

Klinginsmith, James W. (C)

OKLAHOMA CITY

Harvey, Opel L. (B)

OLEAN-BRADFORD

Burch, Phil S. (C)

PHILADELPHIA

Belden, Arthur B. (B)
Gordon, Howard F. (B)
Harlow, Ellis (C)

PITTSBURGH

Caplan, Joseph S. (C)
Foltz, Donald R. (B)
Frankhouser, Wm. L. (B)
Guthrie, Clyde E. (C)
Kenna, Bill (B)
Martini, G. D. (C)
Minnotte, William P. (B)

PROVIDENCE

Johnson, James P. (B)

PUGET SOUND

Porter, Clyde C. (B)
Wallenberg, Waldemar H. (B)

RICHMOND

Phillips, Thomas B., Jr. (C)

SAGINAW VALLEY

Diaz, Quentin J. (C)

SALT LAKE CITY

Hammerstein, Allan W. (C)
Heiner, William W. (B)

SAN FRANCISCO

Allwein, George R. (B)
Anderson, Cecil B. (B)
Betzer, Dwight E. (B)
Christensen, Victor A. (B)
Cottrell, Charles T. (B)
Johnston, Andrew L. (B)
Laranjo, Fred F. (B)
McCallister, Philip Herman (B)
Reed, Henry A. (B)
Waite, Robert B. (B)

SANTA CLARA VALLEY

Hunter, Waldo E. (B)
O'Neill, R. A. (B)

SHREVEPORT

Russum, R. K. (B)

STARK CENTRAL

Carrothers, L. C. (C)
Embly, William S. (C)
Porter, Wm. A. (B)
Wagner, William S. (B)

YORK-CENTRAL PA.

Smith, Jay R. (C)

MEMBERS NOT IN SECTIONS

Gerla, Luigi (B)
Sostero, Orazio (B)

Members Reclassified

During the month of June

ALBUQUERQUE

Volek, Charles W. (D to B)

BOSTON

Johnson, Earl E. (C to B)

LOS ANGELES

West, Leo M. (C to B)

NEW JERSEY

Zampieri, E. (C to B)

NEW YORK

Kasanof, David R. (B to A)

ROCHESTER

Barr, Robert J. (C to B)

ST. LOUIS

Persons, W. R. (B to A)

SANTA CLARA VALLEY

Downing, D. H. (C to B)

SUSQUEHANNA VALLEY

Parrish, Ralph W. (C to B)

Current Welding Literature

For copies of articles, write directly to publications in which they appear. A list of addresses is available on request.

Aircraft Manufacture. Manufacturing in Aeronautic Age—Lord Sempill Paper, 1958. B. K. Bucey. *Aircraft Production*, vol. 20, no. 2 (February 1958), pp. 44–47.

Aircraft Manufacture. Welding on Vickers Viscount 800. *Welding & Metal Fabrication*, vol. 26, no. 2 (February 1958), pp. 40–45.

Aluminum Brazing. Aluminum Dip Brazing Produces Strong, Clean Assemblies Rapidly at Less Cost. M. E. James. *Western Metalworking* (formerly Western Metals), vol. 16, no. 1 (January 1958), pp. 41–43.

Aluminum Busbars. Factors That Shape Weldability of Aluminum Bus. *Welding Engr.*, vol. 42, no. 11 (Nov. 1957), pp. 39–42; vol. 43, no. 1 (January 1958), pp. 34–37.

Aluminum Coatings. How to Work Aluminum-Coated Steel. W. E. McFee. *Iron Age*, vol. 181, no. 6 (Feb. 6, 1958), pp. 95–97.

Atomic Energy. Application of Welding in Atomic Energy Field. L. Rotherham and I. H. Hogg. *Iron & Coal Trades Rev.*, vol. 175, no. 4664 (Oct. 11, 1957), pp. 867–868.

Automobile Manufacture. Welding Avoids Deep Drawing Problems. *Tool Engr.*, Vol. 40, no. 2 (February 1958), pp. 104–106.

Automobile Transmissions. New Tooling for New Dynaflow Transmission. C. H. Wiek. *Machy.* (N. Y.), vol. 64, no. 6 (February 1958), pp. 124–127.

Brazing. Flux-Free Brazing in Reducing Atmospheres. N. H. Jones. *Welding & Metal Fabrication*, vol. 26, no. 2 (February 1958), pp. 46–52.

Cast Iron. Ferrous Castings—How to Get More for Your Metalworking Dollar. *Iron Age*, vol. 181, no. 7 (February 13, 1958), pp. 127–142.

Earthmoving Machinery. Automatic Welding with Templet Control and Nesting Fixtures. L. E. Foust and H. Moody. *Am. Mach.*, vol. 102, no. 4 (Feb. 24, 1958), pp. 104–107.

Flame Cleaning. Improved Method of Flame Descaling for Spot Welding. M. Evrard. *Brit. Welding J.*, vol. 5, no. 2 (February 1958), pp. 57–65.

Foundry Practice. Arcair Torch. T. D. Warren. *Welding & Metal Fabrication*, vol. 26, no. 2 (February 1958), pp. 67–70.

Galvanizing. Fabricating Continuous Galvanized Steel. E. W. Horvick. *Steel Processing & Conversion*, vol. 44, no. 1 (January 1958), pp. 43–46; no. 2 (February), pp. 92–94, 103–104.

Gas Cylinders. New Demands on Gas Cylinders Are Met by Reliable Welds. *Welding Engr.*, vol. 43, no. 1 (January 1958), pp. 27–28.

Gas Turbines. Welding Austenitic Stainless Steels. R. R. Roberts. *Iron & Coal Trades Rev.*, vol. 175, no. 4666 (Oct. 25, 1957), pp. 983–985.

Hangars. Fabricated Hangar Doors. *Welding & Metal Fabrication*, vol. 26, no. 2 (February 1958), pp. 53–55.

Hydraulic Turbines. Large Spiral Casings of T-1 Steel. E. L. Seeland. *Am. Soc. Civ. Engrs.—Proc.*, vol. 83 (J. Power Div.), no. PO5 (October 1957), paper no. 1398, 9 pp.

Light Metals. Arc and Bead Characteristics of Aluminium Self-adjusting Arc. J. C. Needham and A. A. Smith. *Brit. Welding J.*, vol. 5, no. 2 (February 1958), pp. 66–76.

Locomotive Manufacture. Welding Applied to Diesel Locomotive Construction. K. S. Black. *Australasian Engr.*, (Oct. 8, 1957), pp. 72–76.

Molybdenum. Found: Deoxidizing Process to Clean Molybdenum for Welding. E. R. Calderson. *Western Metals*, vol. 15, no. 12 (December 1957), pp. 61–62.

Nuclear Reactors. Selection and Welding of Thick Plate for Nuclear Power Applications. A. S. Ailes and W. L. Pumphrey. *Welding & Metal Fabrication*, vol. 26, no. 2 (February 1958), pp. 62–66.

Oil Tanks. API Recommended Practice for Installation of New Bottoms in Old Storage Tanks. *Am. Petroleum Inst.*—Tentative Standard API RP 12H (First Edition, October 1957), 7 pp.

Pipe Lines. Designing, Fabricating, Pressure Piping. J. J. Murphy, C. R. Soderberg, Jr., H. S. Blumberg and D. B. Rossheim. *Heating, Piping & Air Conditioning*, vol. 30, no. 1 (January 1958), pp. 160–164.

Pipe Lines. Republic Keeps Pace with Increasing Requirements for Fusion Welded Line Pipe. W. S. Schaefer. *Am. Iron & Steel Inst.* (Paper for meeting Oct. 23, 1957), 35 pp.

Power Supply. Silicon Rectifiers Improve Features of Arc Welders. E. F. Steinert. *Welding Engr.*, vol. 43, no. 1 (January 1958), pp. 38–39.

Radioactive Materials. Industrial Uses of Atomic Waste. F. C. Livingstone. *Plant Eng.*, vol. 11, no. 8 (August 1957), pp. 95–97, 198.

Resistance Welding. Welding of Plastic-Coated Steel. D. Ewan. *Welding & Metal Fabrication*, vol. 26, no. 1 (January 1958), pp. 22–23.

Resistance Welding Machines. Building General Purpose Spotwelding Machine. O. Larson. *Machine & Tool Blue Book*, vol. 53, no. 1 (January 1958), pp. 128–131.

Sheet Metal. Inert-Gas Tungsten-Arc Welding SAE 4130 Steel Sheet. C. A. Terry and W. T. Tyler. *Welding & Metal Fabrication*, vol. 26, no. 1, (January 1958), pp. 24–31; no. 2 (February), pp. 58–61.

Shipbuilding Materials. Naval Architect's Problems with Ship Plate. D. P. Brown. *Am. Iron & Steel Inst.* (Paper for meeting Nov. 20, 1957), 21 pp.

Silver Alloy Brazing. Brazing Strip Eliminates Rejects. *Steel*, vol. 142, no. 6 (Feb. 10, 1958), pp. 83–84.

Silver Alloy Brazing. Dual Fixturing Boosts Brazing Rate. W. E. Atkinson. *Iron Age*, vol. 181, no. 6 (Feb. 6, 1958), pp. 100–101.

Stainless Steel. Some Metallurgical Aspects of Welding Stainless Steel. F. A. Ball and J. Hinde. *S. African Inst. Min. & Met.—J.*, vol. 58, no. 2 (September 1957), pp. 83–95; (discussion), pp. 95–96.

ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25c from the Commissioner of Patents, Washington, D. C.

2,810,064—Arc-Welding Electrode and Method of Arc Welding. George G. Landis and John E. Carroll, South Euclid, Ohio, assignors to the Lincoln Electric Co., Cleveland, Ohio, a corporation of Ohio.

This patent relates to a method of depositing a weld bead on a steel workpiece and includes the steps of providing a steel core with an insulating coating of a weight substantially equal to the core and containing available iron in approximately 15 to 30% of the total iron in the electrode. This electrode is positioned at an angle of between 0 and 45° relative to the desired weld bead and in the plane thereof. Thereafter an arc is started between the core and the workpiece to burn back the electrode which is held with its end in contact with the workpiece without any intentional longitudinal or transverse movement of the electrode relative to the weld seam.

2,810,807—Electric Welding Holder. Herman E. Luebbers and Roger A. Hanes, Fort Dodge, Iowa.

In this patented holder, a handle housing is provided that has an electro conductive shaft member rotatably mounted in the handle housing and a conductive member is movably mounted in the handle housing. Such last member can be connected to a conductive member leading from the handle housing and be positioned in either locked contact with the shaft member referred to, or else spaced from such shaft member.

2,810,816—Welding Methods and Apparatus—Ethridge E. Hardesty, Balboa Island, Calif., assignor to Fairchild Engine and Airplane Corp., Hagerstown, Md., a corporation of Maryland.

This is a patent on a method of resistance welding comprising the steps of abutting a metal sheet against an edge of a metal element and supporting the metal sheet on one major face of a metal form. This metal form has a plurality of electrically independent conductive paths between its two major faces. Welding current is passed through a series circuit including the metal element, the metal sheet and the metal form to weld the metal element to the metal sheet.

2,810,817—Wire-Mesh Welding Machine. John H. Breins and Hans Mareis, Detroit, Mich., assignors to Expert Die & Tool Co., Inc., Detroit, Mich., a corporation of Michigan.

This patent is on a machine for continuously producing a wire mesh such as is used in concrete reinforcements. The machine includes a plurality of welding electrode jaws on different and movable portions of the apparatus and other special members for the welding action indicated.

2,810,818—Welding of Low-Alloy Steel. Gilbert R. Rothschild, Berkeley Heights, and Craig R. Sibley, New Providence, N. J., assignors to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

This patent relates to the welding of a ferrous metal workpiece of a specified composition by use of a consumable ferrous electrode of a specified composition. Thus a direct current, reverse polarity electric arc is established between the metal workpiece and the electrode, and the arc is blanketed by a nonturbulent stream of 90% of argon and 1% oxygen gas, and advancing the electrode to maintain the arc as the electrode material is transferred from the electrode to the metal. Thus a weld having a high yield strength and resistant to impact is formed.

2,811,625—Hot Working of Titanium Alloy Welds. Alfred W. Klein, Pittsburg, Pa., assignor, by mesne assignments to the United States of America as represented by the Secretary of the Navy.

This patent is on a method of welding metals by butt welding two sheets of metal by an inert gas-arc method and then passing the resultant joint under the wheels of a resistance seam welder under appropriate heat and pressure.

2,811,630—Heat and Time Switching Welder Control. Kenneth M. Spencer, Wellsboro, Pa., assignor to Sylvania Electric Products, Inc., a corporation of Massachusetts.

This patent relates to a controlling circuit for use with welding apparatus having electrodes movable into engagement with parts to be welded. A circuit is provided for connecting electrodes to a source of electrical potential and switch means are provided in the circuit. A timing circuit is coupled to the switch means and arranged to open them an interval after the engagement of the electrodes with the parts being welded. The timing circuit is connected in parallel with a portion of the circuit and in series with the electrodes so that current flowing through the electrodes will initiate operation of the timing circuit.

2,812,274—Thermochemical Scarfing Process. Ivan P. Thompson, Elizabeth, William Allmang, Bloomfield and William C. Weidner, Summit, N. J., assignors, by mesne assignments, to Union Carbide Corp., a corporation of New York.

The present patent relates to a process for thermochemically scarfing metal bodies and it includes the steps of confining the inside and outside of a supply of oxidizing gas to form a stream of substantially uniform thickness which is discharged onto a reaction zone extending across a metal body and at an acute angle of impingement. The outside of the stream of gas is confined farther along the stream towards the reaction zone than the inside of the stream for a distance greater than the thickness of the stream.

2,812,275—Protective Coating for Salt Bath Brazing. Allen Charles Francisco, Berea, and Charles Anthony Gyorgak, Cleveland, Ohio, assignors to the United States of America as represented by the Secretary of the Navy.

This patent relates to a protective coating for brazing materials in salt bath brazing. This novel coating is made up of 100 parts graphite, 10 parts clay and 1 part binder of a specified composition, which binder coats both the graphite and clay particles present.

2,812,417—Method and Machines for Producing a Butt Seam Joint by Means of Resistance Welding. Ferdinand Busse and Albert Schmitt, Munich, Germany.

The present patent relates to an automatic resistance type welding machine employing a specialized welding process by which two metal welding strips are secured to a pair of sheets at a welded juncture formed therebetween.

2,812,418—Portable Resistance Welding Gun—Alexander John Allan, Don Mills, Ontario, and Peter Harry Booth, Rexdale, Ontario, Canada, assignors to Orenda Engines Ltd., Village of Malton, Ontario, Canada, a corporation.

The patented welding device includes a plunger mounted for sliding movement relative to a guide member and biased in one direction. This plunger is adapted to carry an electrode extending in the direction of the bias. A switch is fixed on the guide member for connecting the welding device to the source of electric current and means carried by the plunger engage a member extending into its path of movement to actuate the switch. A trigger is provided to actuate the switch, while another member is also provided for rendering the plunger and the trigger selectively inoperative for actuating the switch.

NEWS of The Industry

Hobart Completes School to Train Technicians and Operators

Since 1930, over 20,000 welders have been graduated from the Hobart Brothers Technical School in Troy, Ohio. In the very midst of World War II, this same school, operated by the Hobart Brothers Co., turned out as many as 190 students per day to fill responsible positions in the swollen effort of war production.

On June 30, 1958, the Hobart concern completed construction of a new building with 80,000 sq ft of floor space to further the training of welding operators for the welding industry. But by 1959 Hobart officials expect to include a more advanced program for the student.

The new school contains 120 welding stations for use in the instruction of arc- and gas-welding equipment, numerous classrooms, demonstration areas, a technical library, a 400-seat auditorium complete with projection equipment, laboratories, research and testing facilities and an X-ray and radioisotope room.

Although there is a great need for engineers in the welding industry there will be a greater need yet for welding technicians in the years to come. The more advanced program which company officials plan for 1959 would include the present 16-week course for welding operators in addition to basic studies of electricity, metallurgy, chemistry, physics and math. Blueprint reading, drafting, layout, welding design, strength of materials and specialized subjects based on such AWS texts as codes, testing and safety would also be included in the new curriculum. Completion of such a course would require from 9 to 12 months.

Hobart officials maintain that such a course could possibly evolve into a two-year "welding associate" or "junior college" type program in the near future. Company officials announced that the current welding operator school would continue as usual.

This new Hobart Brothers Technical School, Troy, Ohio, covering 80,000 sq ft of floor space, is devoted to teaching, research and development in the welding field on a nonprofit basis

Close-up of the gas-welding section at the Hobart School shows testing facilities and metalworking equipment in the background

120 welding stations for training students in the use of all types of arc- and gas-welding equipment are included in the large training section

WANTED

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FOR

AWS 40th ANNUAL MEETING

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August 15, 1958

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1959 Spring Meeting and Welding Show:
April 6–10, Sherman Hotel, Chicago, Ill.

ASM

October 27–31, 1958. 40th National Metal Exposition & Congress. Cleveland Public Auditorium, Cleveland, Ohio.

Midwest Welding Conference

Jan. 28–29, 1959. Illinois Institute of Technology, Chicago. Sponsored by Armour Research Foundation and AWS Chicago Section.

IAA

Mar. 9–11, 1959. Annual Meeting. Roosevelt Hotel, New Orleans, La.

Western Metal Exposition

Mar. 16–20, 1959. Eleventh Western Metal Exposition and Congress, ASM and other technical groups, Pan-Pacific Auditorium and Ambassador Hotel, Los Angeles, Calif.

Fifth Nuclear Congress

April 5–10, 1959. Public Auditorium, Cleveland, Ohio.

NWSA

May 4–7, 1959. Annual Meeting. Fairmount Hotel, San Francisco, Calif.

INTERNATIONAL WELDING NEWS

By Dr. Gerard E. Claussen

East Germany Completes Reactor

On Dec. 16, 1957, the first research reactor was completed in Dresden, according to the East German welding magazine.[1] The parts from which the atomic reactor was built were supplied by Russia, while East German engineers assembled and installed the reactor. Before autumn of this year a cyclotron (120-ton magnet) is expected to be installed in the same laboratory as the reactor. Several welding problems can be studied now that the reactor can supply isotopes. Radioactive carbon will be used to study carbon diffusion in joints between austenitic and ferritic steels. The extent to which electrode coating constituents enter the weld metal will also be studied.

Qualification Exams in Welding Engineering

The same magazine[2] outlines the examinations given to candidates for the degree of welding engineering at the Central Welding Institute in Halle. Two courses of instruction are offered: one for men interested in design of structures, the other for men interested in welding technology. The course for the latter occupies eight weeks and covers the following main topics: (1) metallurgy and materials testing, (2) gas welding and cutting, (3) manual-arc welding, (4) automatic arc and electroslag welding, (5) inert-arc and resistance welding, (6) production and quality control, (7) design of structures, (8) plant visits, (9) review, and (10) examinations: 8 hours written, 15 minutes oral. Those who pass the examinations qualify as welding engineers in the sense of the important German specifications.

Steel for Welded Structures

The director[3] of the Central Welding Institute in Halle describes the use of general low-carbon unalloyed steel for welded structures, such as cranes. The well-known medium-manganese steel (ST52) requires imported manganese ore, is difficult to roll, and costs 56 marks more per ton than mild steel. Quenching plain carbon steel from rolling heat costs only 5 marks per ton. A steel containing 0.13% C, 0.25% Si, 0.48% Mn, 0.034% P, 0.045% S, and 0.005% N_2 had 41,000 psi yield strength, 56,000 psi tensile strength, as-rolled, and 51,000 and 80,000 psi, respectively, after being quenched. The quenched steel had better impact properties after aging than normalized material.

Poland Issues Specifications for Welded Bridges

A description of the new Polish specifications[4] for welded railway bridges is prefaced by statements that the first all-welded highway bridge in the world was erected at Lowice, Poland in 1929, and the first welded truss-type railway bridge with riveted field joints was built in Poland in 1938. The steel in the new specifications must contain 0.10–0.20 % C, 0.040 max % P, 0.045 max % S, 0.080 max % S + P, and 0.12–0.22 % Si. The tensile properties must be 32,700 psi min yield strength, 52,500–67,000 psi tensile strength. The permissible stress in tension, compression and bending is 20,000 psi for main loads. Some of the stress-concentration factors in fatigue are:

- base metal at a distance from a notch —1.00
- base metal with rivet holes—1.10
- base metal at unmachined junction with butt weld—1.30
- base metal at machined junction with butt weld—1.00
- base metal at unmachined junction with end fillet weld—3.00
- base metal at machined junction with end fillet weld—2.00
- side fillet weld—1.10

Russians Report on Submerged-Arc Weld Metal

A Russian investigation[5] reports on the effect of carbon, phosphorus and nickel on the Charpy-V notch-impact value of submerged-arc weld metal deposited at 500 amp, 26 ipm. The welds were deposited in one or two layers and were tested at +68, −94 and −256° F. Carbide-forming elements and nonhomogeneous structure were injurious to low-temperature toughness. An increase in carbon from 0.07 to 0.11% was harmful, as was an increase in phosphorus from 0.015 to 0.030%. The first 1% of nickel was beneficial, but further increases to 3.5% provided no additional benefit. In order to secure good results at −256° F the weld metal had to be heat treated and had to contain 0.06–0.10% C, 0.014–0.022% P and 2.0% Ni min. Further lowering of carbon and phosphorus may have been beneficial but was not practical. Heat treatment involved water quenching after 2 min at 1670° F with or without subsequent drawing at 1130° F. Air cooling or longer hold at 1670° F was harmful. Good impact properties at −94° F were secured with as-deposited metal containing 0.10% C, 0.030% P and 1.0% Ni.

Soviet Scientists Study Impact Behavior

An attempt was made by Russian investigators[6] to relate low-temperature impact behavior of submerged-arc weld metal in mild- and low-alloy steel to three factors: macrostrain, lattice strain and the size of ferrite blocks in electron micrographs. Macrostrain developed by welding under restraint and also lattice strain were found to be subordinate in importance to the size of the ferrite blocks in the structure. A high rate of cooling provided by welding on plates at −94° F produced higher impact value at 76° F and finer electron-micrographic structure than by welding plates at +68 or 1020° F.

Autoradiography Used by Russians

The segregation of sulfur in submerged-arc weld metal deposited at 850 amp with high-manganese flux was measured[7] by autoradiography. Sulfur isotope was added to the weld to permit estimation of the degree of segregation from the relative intensity of the dendritic pattern in micro-autoradiographs. The results showed that segregation was reduced by 2.0–2.5% Mn in welds containing 0.30% C, but not in welds containing 0.11 % C. It was not shown whether cracking depended on degree of segregation, but with over 0.20 % C, increasing the manganese to 2.5 % did not prevent cracks.

Russians Weld Plates Without Preheat

It was possible in Russian tests to weld 1½-in. plates of steel[8] containing 0.18 % C, 12.3 % Cr without preheat, but to secure desirable properties and structure in the heat-affected zone the welds had to be stress relieved at 1290–1380° F. The electrode contained 0.08% max C and 13–15% Cr, and was

Dr. Gerard E. Claussen is associated with the Development Laboratories, Linde Co., Newark, N. J.

deposited in V joints at 370 amp, 16 ipm, using carbon-dioxide shielding gas.

Arc Welding in Germany

The melting rate of one bare and four covered electrodes was measured by Stieler[9] over a range of currents. The width of the heat-tinted zone adjacent to the beads was also measured. The bend ductility, tensile strength and notch impact of welds made at the manufacturer's recommended current, as well as those 20 amp higher and lower, were reported. The lower currents lowered the bend ductility, while the higher currents lowered the impact value slightly.

Problems in CO_2 Welding in USSR

The loss of oxidizable elements from the electrode in CO_2 welding of steel was found by a Russian writer[10] to depend on the time available for the reaction of the drops of metal with the atmosphere. The coefficient of reactivity was expressed as $C = ST/P$ mm^2 sec per gram, where S = surface area of drops, T = time during which a drop exists and P = weight of a drop. Increasing the arc voltage or lowering the rate of electrode feed increased the loss by oxidation. The fact that oxidation was greater on straight than on reverse polarity could not be explained by the coefficient C.

Soviet Laboratory Investigates Generator

To improve self regulation of welding arcs in protective gases, a Russian laboratory[11] recommends a generator with a rising characteristic and independent excitation.

Germans Study Rutile Coatings

Vibrating a rutile type of covered mild-steel electrode raised the melting rate 20 to 25%, increased the penetration a great deal and prevented sticking on striking the arc, according to Tybus.[12] The vibration was longitudinal, 50 cycles per sec, with some unavoidable lateral vibration. A very short arc could be held with vibration. With an austenitic steel electrode, vibration increased the melting rate and penetration and almost eliminated spatter. The vibrating electrode has not been used in production yet.

Titanium Stabilizers

The alloying elements[13] that provide the highest strength in titanium welds are those that stabilize the beta phase, namely: Mn, Fe and Cr. Copper and vanadium are less effective. For welds that cannot be heat treated, 4 to 5% of aluminum or tin together with 2 to 3% of beta-stabilizing elements, provide good ductility. Of the elements that stabilize beta, molybdenum and copper lower the ductility least. The best structure for notch-impact value consists of finely dispersed alpha in beta.

Pressure Welding Used for Color Matching

Pressure welding processes (flash or cold welding) are best for avoiding color differences in aluminum welds to be anodized, according to German investigators.[14] The darkening of the weld and heat-affected zone after anodizing was most pronounced with aluminum alloys containing 3% magnesium.

Preparation for Cold Welding in Russia

The preparation of parts for cold welding is described by Baranov,[15] who favors the use of rotary wire brushes. Aluminum parts should be heated in air to 660-750° F to remove organic films, then wire brushed. Even trifling contamination, such as fingerprints, prevents cold welding. Copper parts should be rubbed with a clean dry rag. Chromium plated parts are unsuitable for cold welding, because only low strength can be attained.

References

1. Erdmann-Jesnitzer, F., *Schweisstechnik (Berlin)*, **8**, 93-95 (1958).
2. *Ibid.*, **8**, 118-122 (1958).
3. Gilde, W., *Ibid.*, **8**, 34-38 (1958); *Automat. Svarka*, **2**, 3-8 (1958).
4. Iesniak, Z. K., *Ibid.*, **8**, 96-100 (1958).
5. Ostrovskaya, S. A., *Automat. Svarka*, **2**, 42-52 (1958).
6. Kasatkin, B. S., Kareta, N. L., and Darevsky, G. F., *Ibid.*, **2**, 20-29 (1958).
7. Poznyak, L. A., *Ibid.*, **1**, 80-86 (1958).
8. Kakhovsky, N. I., *Ibid.*, **2**, 30-36 (1958).
9. Stieler, C., *Schweissen u. Schneiden*, **10**, 119-125 (1958).
10. Potapevsky, A. G., *Automat. Svarka*, **2**, 53-58 (1958).
11. Shchitova, A. M., and Rykunova, I. Ya., *Ibid.*, **1**, 43-47 (1958).
12. Tybus, G., *Schweisstechnik (Berlin)*, **8**, 101-105 (1958).
13. Gurevich, S. M., *Automat. Svarka*, **1**, 14-21 (1958).
14. Ruge, J. and Zitzelsberger, W., *Schweissen u. Schneiden*, **10**, 125-131 (1958).
15. Baranov, I. B., *Automat. Svarka*, **1**, 63-70 (1958).

New Name for Jersey Distributor

A New Jersey distributor has changed its name. Formerly trading as Welding Sales Co. the firm is now known as Gasare Welding Sales Co. and will continue to conduct business from 24 Park Ave., West Orange, N. J. The company has also been appointed a distributor for compressed gases throughout the state of New Jersey, representing the Thomas A. Edison Co.

Changes at Nelson

Several personnel changes have been announced recently by Nelson Stud Welding Division, Gregory Industries, Inc., Lorain, Ohio.

George A. Medsker has been appointed Cleveland branch manager and will direct sales and customer service within a 5-state territory. George A. Kennedy has been given a similar assignment to direct a 7-state territory from the company's Chicago branch office. Robert C. Friendly and Harold A. Hallstein, Jr., have both been appointed product sales managers and will apportion most of their sales time toward construction applications.

New Location for St. Louis Dealer

Cee-Kay Supply Inc., authorized dealer for National Cylinder Gas Co., has moved to larger quarters at 4244 Folsom Ave., St. Louis, Mo.

NCG Division representatives cooperated in a clinic with demonstrations of flame-cutting and welding, inert-arc welding and other processes, when Cee-Kay dedicated its new facilities, which officials said were required by substantial growth in its services to the welding industry.

Dividends from M & T

Directors of Metal & Thermit Corp., at their regular meeting, declared a dividend of 30 cents per share on the common stock, it was announced by H. E. Martin, president.

The dividend was payable June 13, 1958.

The directors also declared the regular quarterly dividend of 87½ cents per share on the preferred stock, payable June 27, 1958.

NEW J & L OXYGEN FACILITY

Air Products facility at Aliquippa, Pa. supplies 230 tons per day of 99.5% pure oxygen for the new "basic oxygen process" of Jones and Laughlin Steel Corp.

Welded Aircraft Carrier Launched in New York

An aircraft carrier containing over 3,000,000 lb of weld metal was launched on June 6th at the New York Naval Shipyard. On hand to witness the christening of this fourth carrier of the Forrestal class, the *USS Independence*, were AWS President G. O. Hoglund and National Secretary Fred L. Plummer. The vessel contained a plant to produce oxygen fuel for her jet aircraft.

The *Independence* was christened by Mrs. Thomas S. Gates, Jr., wife of the Secretary of the Navy. The principal address at this event was delivered by Deputy Secretary of Defense Donald A. Quarles.

ASM Introduces Home-Study Course in Oxyacetylene Welding

The Metals Engineering Institute, a division of the American Society for Metals, Cleveland 3, Ohio, has announced an illustrated home-study course in 15 lessons on oxyacetylene welding. The preparation of the new course was supervised by John H. Zimmerman, manager of Gas Processes of the Linde Co., a division of Union Carbide Corp.

The course treats such subjects as metallurgy, scope of operations, equipment, physical setup, metal properties, preparation of metals for welding and the constitution and properties of ferrous alloys. Other chapters discuss fusion welding, braze welding and silver brazing, in addition to wear resistance, heat treatment and manual and machine flame cutting. Production welding and inspection are also covered as are helpful hints of operating a small welding shop.

Futher information can be obtained by writing to Metals Engineering Institute, 7301R Euclid Ave., Cleveland 3, Ohio.

NCG Appoints District Managers

The National Cylinder Gas Division of Chemetron Corp., Chicago, has appointed new managers for the Cincinnati and Columbus, Ohio, and McKees Rocks, Pa., districts of its North Central region.

Otto H. Wilhelm, district manager at McKees Rocks since 1954, was appointed manager of the Columbus district, succeeding the late C. A. Clark.

A. D. Fischer, district manager at Cincinnati since 1956, was named to fill the McKees Rocks post; and Charles H. Diment, assistant district manager since 1953, was promoted to manager of the Cincinnati district.

Aronson Appoints Six Dealers

Six companies located throughout the country have been authorized to represent Aronson Machine Co. of Arcade, N. Y. The concerns are Airline Welding and Engineering Co., Hawthorne, Calif.; Texas Welding Supply Co., Dallas, Tex.; Arcet Equipment Co., Richmond, Va.; Dye Oxygen Co., Inc., Phoenix, Ariz.; Kirk-Wiklund Co., Kansas City, Mo.; and R & R Welding Supply Co., Des Moines, Iowa.

41 Airco Plants Win Safety Awards

Forty-one Air Reduction plant locations in the United States and Canada have been awarded certificates of safety achievement for 1957 by the Manufacturing Chemist's Assn., Washington, D. C. The awards, which are given annually to those plants which complete a calendar year without a lost-time accident, have been made to only 397 plants, representing 46 companies, throughout the country.

With respect to the total number of plant location safety certificates received, Air Reduction ranked among the top three companies in the nation. During the same period, an additional 14 Air Reduction facilities were operated without a disabling injury but were ineligible in terms of required man-hours to qualify for the MCA awards.

Linde to Build Liquid-Gas Plant in California

Linde Co., Division of Union Carbide Corp., will build a new 300 ton-a-day producing plant at Pittsburg, Calif., according to an announcement by Morse G. Dial, corporation president. Production capacity in 10 months will be 115 million cu ft per month. A few months later, when additional equipment will go on stream, the plant will have a total capacity of more than 220 million cu ft per month.

Lincoln Opens Memphis and Albany Offices

The Lincoln Electric Co. has announced the opening of two new district offices in Memphis, Tenn., and Albany, N. Y.

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To get these production savings, Dominion decided to assemble the tank by furnace brazing rather than welding. For the tank bottom, they used new alclad No. 100 Brazing Sheet with a special inner cladding of alloy 7072 to protect the core metal against penetration. No. 718 Brazing Alloy, in the form of shims or flattened wire, was used to join other parts of the tank assembly. Five components are furnace-brazed in *one single operation*.

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WISCONSIN
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Robert W. Thomas moved from the Philadelphia Office to become district manager in Memphis. An Ohio State University graduate in engineering, Mr. Thomas joined Lincoln in 1947 in the Columbus Office.

Russell S. Hale has been appointed district manager of the new Albany Office. He received his degree in electrical engineering from the University of Nebraska in 1950, and worked in Lincoln's Chicago office before moving to Albany.

NCG Appoints Dealer in Michigan

Northern Welding Supply Co., 2401 E. Michigan Ave., Jackson, Mich., has been appointed an authorized dealer by the National Cylinder Gas Division of Chemetron Corp., Chicago. The firm, headed by J. H. Colwill, will handle the entire line of NCG industrial gases, arc-welding equipment and flame cutting and welding equipment. Mr. Colwill is also president of Detroit Gas Products Co., Royal Oak, Mich., another authorized NCG dealer.

Educational Program at Stevens

Three new courses in metallurgy will be offered at the Industries Training School at Stevens Institute of Technology, Hoboken, N.J., during the 1958–59 academic year, it was announced by I.T.S. Director L. Edwin Backer.

The first of the courses, "Properties of Metals," will be given on Wednesday evenings during the fall semester, starting Sept. 25, 1958. During the spring semester, starting Feb. 9, 1959, the other courses, "Metal Joining, Light Assemblies," and "Metal Joining, Heavy Assemblies," will be offered on Tuesday and Thursday evenings, respectively.

Among the topics to be covered in "Properties of Metals" will be physical metallurgy; heat treatment of steels; properties of various steel, copper and light metal alloys; and powder metallurgy.

"Metal Joining, Light Assemblies" will contain material on all joining processes with emphasis on soldering, brazing, resistance welding and adhesives. "Metal Joining, Heavy Assemblies" will also contain material on all joining processes, but will emphasize the various arc-welding processes. Tuition for each of the three courses is $50 and there is a $5 registration fee for each sixteen-week semester.

All courses offered by the Industries Training School are of college level but may not be applied toward a college degree.

Alloy Rods Names Two Distributors

Alloy Rods Co. announces the appointment of Lacey Automotive Parts Co., 108 Monterey St., Salinas, Calif., and Engle Welding Supply Co., 1120 Grand Ave., Des Moines, Iowa., as distributors who will handle the York, Pa., concern's line of welding electrodes and hard-surfacing materials.

French Concern to Manufacture Ampco Welding Line

Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis., announces that the government of France has approved a licensee arrangement between the Milwaukee organization and Sarazin & Cie, 47, 49 Bld. de Levallois, Neuilly-Sur-Seine, for the exclusive manufacture in France of Ampco-Trode covered electrodes, filler rod and spooled wire to be sold under Ampco's trade name.

Sarazin & Cie, one of the largest manufacturers of arc-welding equipment, steel electrodes and accessories in France, will market the Ampco line solely in France. It is anticipated that the French firm will eventually offer the Ampco products to the entire European industry.

Canadian Welding Seminar

Leading authorities in the welding field from Canada, Britain and the United States took part in the National Welding Seminar held in Toronto, June 2-6. Sponsored by the Canadian Welding Society and the University of Toronto, University Extension, the course provided a program of lectures and discussions on welding fundamentals and shop practice.

From Britain, Dr. A. A. Wells and P. T. Houldcroft, both of British Welding Research Association, discussed welding research in the United Kingdom.

Professor C. D. Jenssen, Fritz Engineering Laboratory, Lehigh University, spoke on "Structural Welding and Plastic Design." His paper covered designing of shapes for efficient structures and use of the plastic hinge in economical design.

In the sessions devoted to materials for welding, H. Thielsch, Grinnell Co., Providence, R. I., looked at the high tensile steels, ultra high strength structural steel and pressure piping materials in a paper on "Welding Low Alloy Steels."

Professor R. B. McCauley, Department of Welding Engineering, Ohio State University, discussed the role of the welding engineer and outlined techniques for taking back seminar information to other members of the par-

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tieipant's organization.

Dr. W. C. Winegard, Department of Metallurgical Engineering, University of Toronto, spoke on "Basic Structure and Properties." His paper covered solidification, dislocation and impurities, working, annealing and weld analogies.

Design trends in welded fabrication of pressure vessels was dealt with by C. A. McDonald, Horton Steel Works, Fort Erie, Ontario, in a paper entitled "Welded Pressure Vessel Design." L. Jehu, Dominion Bridge Co., Lachine, Quebec, discussed the thermal effects of welding and dimensional control by design and procedure.

Harry Thomasson, Canadian Westinghouse Co. Ltd., Hamilton, Ontario, led a panel discussion on the costs of arc-welding methods, in the sessions on "Cost Reduction by Welding." The panel went into comparisons of manual, submerged-arc and inert-gas methods. "Standards and Quality Control" was the subject of a paper by R. M. Goodcrham, Canadian Welding Bureau, Toronto, Ontario.

Resistance-Welding Merger

The American Industrial Equipment Co. of Union City, N. J., rebuilders of resistance-welding equipment, and Ralph Hochman & Co., of Newark, N. J., have recently organized The American-Hochman Welder and Machinery Corp. in Philadelphia. This new organization, managed by John R. Suplee [illegible], specializes in new and rebuilt resistance-welding equipment, supplies and service and also new and rebuilt metal-working tools. The company is located at 119 N. 3rd St., Philadelphia 6, Pa.

Pureco Sets Up Pacific Region

J. J. Lincoln, Jr., president of Pure Carbonic Co., a division of Air Reduction Co., Inc., has announced the formation of a Pacific Region comprising the Berkeley, Los Angeles, Portland and Seattle districts.

D. C. Giles, formerly district manager at Berkeley, has been appointed regional manager. He will be responsible for all sales, distribution and field administration functions for the new region.

In another move D. B. Clapp, Jr., formerly district sales manager at Los Angeles, was appointed regional sales manager.

Burdett Oxygen Opens Branch in Detroit

A new branch of the Burdett Oxygen Co. of Cleveland, Ohio, has been opened in Detroit, Mich., at 20137 Sherwood Ave., near the 8-Mile Road. J. E. Rooney, recently appointed general manager of the Detroit unit, and Leonard Holton, assistant manager, will direct activities at the new branch.

The opening of the Detroit branch marks a third step in an expansion program for Burdett Oxygen that includes the recent construction of two separate million-dollar liquid oxygen plants in Cleveland and Santa Fe Springs, Calif.

KSM Opens Plant in Canada

KSM Products, Inc., Merchantville, N. J., has opened a manufacturing plant and sales office at 379 Bering Ave., Toronto, Ontario. Sales manager for the new subsidiary will be William Pennycook, while George Inward and Arthur Catalfamo will represent the company as sales engineers. Earl Wells has been named plant supervisor in Toronto. The Canadian firm will be known as KSM of Canada, Ltd.

WELDED DESIGN PAPERS

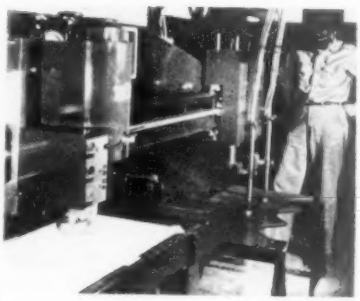
Wanted for

AWS 40th Annual Meeting

Deadline for Abstracts:

August 15, 1958

ELECTRONIC TRACER INTRODUCED



Flame-cutting torches are guided by the first electronic line tracer for flame shape-cutting machines in the United States, according to an announcement by the NCG Division of Chemetron Corp. The new optical "sensing" system, developed for NCG by Canadian Westinghouse Co., Ltd., steers steel-cutting torches by "reading" ordinary pen or pencil line drawings, reducing cost of pattern preparation by an estimated 75%

BUSINESS IS WHERE YOU FIND IT

Two AWS members, Andy Axtell (*left*) and Clayt Herrick (*right*), are being guided through the Lago refinery on the island of Aruka in the Netherlands Antilles by Henri M. Nassey of the Standard Oil subsidiary. Messrs. Axtell and Herrick are respective presidents of Essex Welding Equipment Co., Newark, N. J., and C. B. Herrick Mfg. Corp., Cleveland, Ohio. A great amount of welding is being done at the South American installation

Weldynamics

ARC WELDING AT WORK CUTTING COSTS

Weld questionable steels with . . .

JETWELD LH-70

- *Outstanding overhead and out-of-position operation*
- *High physical properties*
- *Fast, easy iron powder action*

Jetweld LH-70 operates overhead with the smooth, fast action—and has the high physical properties of a low hydrogen rod.

Produces crack-free welds on heavy plate with a minimum of stress relieving. Reduces the need for preheat on medium carbon steels—makes porosity free welds on sulphur bearing steel.

A.W.S. Classification E-6016.

Look for the three dots • • • symbol of Lincoln quality. Weldirectory of Lincoln mild steel electrodes Bulletin 7000.1 sent free on request.

The World's Largest Manufacturer of Arc Welding Equipment

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THE LINCOLN ELECTRIC COMPANY, DEPT. 1943 CLEVELAND 17, OHIO

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SAFETY
ECONOMY

HI-AMP®
GROUND CLAMPS

- Spring cannot be knocked out.
- Spring adjustment screw for easy replacement or adjusting.
- Sturdily built for excessive abuse.
- Designed especially for all-around welders needs.

LENCO, INC.
Box 189, Jackson, Mo.

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Ampco Opens Texas Center

Ampco Metal, Inc. officially dedicated its new $250,000 foundry and Southwest sales center recently in Garland, Tex.

The new 15,000-sq ft facility contains modern sand and centrifugal casting facilities from which Ampco will produce bronze castings ranging in size to more than 2000 lb. This is double the originally announced capacity for such castings and represents upgrading of the scope of the Ampco operation here since first announcement in mid-1957.

KSM Expands Sales Staff

KSM Products, Inc., Merchantville, N. J., has announced new appointments in four of the company's sales regions. Walter A. Kiel will direct sales in the northeast region from New York City, with Vincent Fisco servicing the northern New Jersey area. Within the eastern region Charles P. Baker will be sales engineer, operating out of the newly created sales office in Pittsburgh. Two more new sales offices in the southeast region were opened in Raleigh, N. C., and New Orleans, with Arthur Marriott and William Bodine, respectively, acting as sales engineers. Nelson W. Gillis was named sales manager in the Chicago headquarters of the central region. In other company moves, Claude Batuk was transferred from Chicago to the home office in Merchantville while Howard Berndt and Joseph Golden were added to the Chicago sales staff.

Minnesota Representation for Peck

Welding Supply & Specialty Co., St. Paul, Minn., has been appointed to represent the Cecil C. Peck Co.'s lines of automatic welding manipulators and fixtures. Ray T. Schwabe, president of Welding Supply, states that the Peck lines supplement the company's present representation of Smith Welding Equipment Corp., Arcos Corp., The Tee Torch Co., Inc. and Sylvania Electric Products, Inc.

CB & I Moves Facility

Chicago Bridge & Iron Co., Chicago, has announced the movement of its Houston Erection District facilities to new quarters on an 85-acre site northeast of Houston, Tex., to provide space for future expansion.

The Houston Erection District facilities—including a warehouse, maintenance and field construction equipment, plate rolls, edge preparation equipment and a crane runway—were formerly located on a three-acre tract on Clinton Drive, Houston.

WINS LINCOLN AWARD

Robert V. May, owner of the R. V. May Co., Prestonsburg, Ky., is shown receiving the Lincoln Electric "Weldealer of the Year" award from F. H. Smith, district manager, and Robert M. Losee, welding engineer, both of the Lincoln organization. The award cites the company for "outstanding achievements in performance, cooperation, development and leadership." "Honorable mentions" were presented to Mark Twain Supply Co., Hannibal, Mo., and Edgar Stumpf, Muscoutah, Ill.

WELDING LIBRARY IMPROVED AT OHIO STATE

A welding patent classification system has been added to the A. F. Davis Welding Library at Ohio State University which files over 15,000 patent specifications. The library houses 5800 books on welding. Shown in the library are Prof. Roy B. McCauley, chairman of Ohio State's welding engineering department, and Mrs. Ava Gordon, librarian

Unique Appoints Distributor

Unique Equipment, Inc., 122 Sumpter St., Brooklyn 33, N. Y., announces the appointment of Anderson Equipment Co. of Los Angeles as a franchised distributor for the firm's line of positioning equipment.

Anderson Equipment will cover the Los Angeles and neighboring area.

Narda Ultrasonics Acquires Alcar

The Narda Ultrasonics Corp., Mineola, L. I., has acquired Alcar Instruments Inc., Little Ferry, N. J., according to an announcement by Paul M. Platzman, Narda's vice-president in charge of sales.

Alcar, founded in 1953, specializes in ultrasonics research and development, and is a supplier of custom-built systems and high-powered ultrasonic equipment and special devices to industry and government.

Commenting on the acquisition, Mr. Platzman said: "The combined operations of the two companies will now permit users of ultrasonic equipment to consult with one source on any electro-acoustic problem in the field. We are now able to supply everything from the smallest stock-model ultrasonic cleaner to the largest and most complete industrial ultrasonic system—including such heavy-duty applications as cleaning, chemical and physical processing, nondestructive testing and flaw detection, soldering, welding and drilling."

Westinghouse Report

Westinghouse Electric Corp. sales billed in the first quarter of 1958 were $449,329,000, and net income was $12,903,000 equal to 73 cents a common share, Chairman of the Board Gwilym A. Price has reported to the directors.

The first quarter billings were 5.5% below the $475,686,000 billed in the first quarter of 1957. However, new business booked in the quarter exceeded sales billed, Mr. Price said.

Executive Appointments at Smith Welding

Recent executive appointments at Smith Welding Equipment Corp., Minneapolis, Minn., include P. L. Taylor, elected vice-president in charge of Production and Personnel; Ed Langston, appointed district manager of the southeastern area; Ray Cain, named west coast district manager; and H. L. McElhoe, made director of training, a newly created post operating within Smith's Research and Development Department.

In addition, Smith announces the appointment of 5 new territory managers within the United States proper and 1 additional man whose area will be export sales. These men are Gene Hill, operating out of Charlotte, N. C.; Frank Kolb at Little Rock, Ark.; Ray Puryear [illegible] of Chicamauga, Ga.; Len Stuart of Dallas, Tex.; Wes Westerson, of Ferguson, Mo.; and Dick Weimar whose duties will be export sales with headquarters at the home office, Minneapolis, Minn.

HARRIS CALORIFIC HOLDS DISTRIBUTOR MEETING

Officials from Harris Calorific Co. are shown in the midst of a two-day meeting with their distributors in which future plans were discussed and new products were introduced. The front row reveals (*left to right*) Gordon Briggs, A. R. Gustofson, Carl Baehr, Bill Scott, Dave Booker, Fred Miller and Carl DeWitt. Seated in the second row are Howard Balthasar, R. Donovan, W. White, R. Brunhouse, E. A. Korl and Frank Howard. Standing are R. L. Rasmussen, Leigh Perkins, R. M. Wright, R. Flannery, Steve Taylor and Dick Boyd

THE *NEW* MILLER
ALL-IN-ONE SPOT WELDER
for
ALL NUMBER ONE WELDS

LECTRO SPOT

Built-in Timer Turns the Trick

Sheet metal shops ready for new speed, economy and completely uniform spot welds will want the new Lectro Spot. Here's why:

Operator depresses lever and,
1 — 2 — 3:
Tongs grip work at pre-set pressure;
Starter switch is actuated;
Weld sequence starts and stops automatically;
Result: EVERY WELD IS IDENTICAL!

Pressure adjustment and electronic timer controls instantly accessible.

Three models in 115 or 230 volts weld mild steel of 1/8" to 3/16" combined thickness; 1.5 KVA weighs 29 lbs., 2.5 KVA weighs 39 lbs.

Wide choice of tongs available.

Complete information sent promptly.

miller ELECTRIC MANUFACTURING COMPANY, INC. Appleton • Wisconsin

Distributed in Canada by Canadian Liquid Air Co., Ltd., Montreal

For details, circle No. 19 on Reader Information Card

PERSONNEL

Schilling Named by Thermacote

F. V. Schilling AWS has been appointed district representative in the states of Ohio, Indiana and Illinois by the Thermacote Co. of Pasadena, Calif., manufacturers of welding supplies and equipment.

F. V. Schilling

Mr. Schilling has been associated with the welding industry for many years, and was formerly connected with the Westinghouse Electric Corp. as district supervisor, Welding Application Engineering.

The Thermacote Co. also announces the appointment of John Schroeder as district representative in Wisconsin, Minnesota, North and South Dakota.

Purdue Professor Elected ASTM President

Kenneth B. Woods, head of the School of Civil Engineering at Purdue University, was elected president of the American Society for Testing Materials at the engineering body's 61st Annual Meeting in Boston during the week of June 22nd. Vice-president for the group for 1958–59 will be A. Allan Bates, Portland Cement Assn., while Frank L. LaQue, vice-president of International Nickel's Development and Research Division, will continue as senior vice-president of ASTM.

Elected for three-year terms on the board of directors were Paul A. Archibald, William L. Fink, Harry M. Hancock, Lawrence A. O'Leary and Alfred C. Webber.

Kotchian, Richardson and Fischer Named by Lincoln

John F. Kotchian AWS, Charles M. Richardson AWS and William F. Fischer AWS have been appointed district managers of The Lincoln Electric Co.'s North Haven, Conn.; Franklin, Pa.; and Phoenix, Ariz., offices, respectively.

Mr. Kotchian joined Lincoln after graduation from Harvard Business School in 1948, and worked in Lincoln's Cleveland and Detroit offices before moving to North Haven.

Mr. Richardson has been with Lincoln since 1936. A graduate of Case Institute of Technology, he started as a welding engineer in Lincoln's Milwaukee office. He also worked in the Des Moines, Toledo and Buffalo offices.

Mr. Fischer has been with Lincoln since 1932, and, prior to that time, was employed by Standard Oil Company of California. He started in Lincoln's San Francisco office as a welding engineer.

Walter L. Green Receives Honorary Degree from Wagner

Walter L. Green AWS, chairman of the board of the American Bureau of Shipping, New York City, received the honorary degree of doctor of science at the 73rd annual commencement exercises of Wagner College, Staten Island, N. Y., on June 1st.

Mr. Green was cited for his outstanding achievements in the fields of marine engineering and naval architecture.

He joined the American Bureau of Shipping, the shipbuilding industry's technical classification society, in 1947 as a vice-president. He was elected president in 1950 and chairman of the board in 1952.

A native of Brooklyn, Mr. Green is a graduate of Pratt Institute. During his 44 years in the shipbuilding industry, he has been associated with the Luckenbach Steamship Co.; the Seattle-Tacoma Shipbuilding Corp.; the New England Shipbuilding Corp.; and the Todd Shipyards Corp.

He is now serving a two-year term as president of the Society of Naval Architects and Marine Engineers. Mr. Green is also president and a member of the board of trustees of Webb Institute of Naval Architecture.

In 1956, he was appointed by the then Secretary of the Treasury, George Humphrey, to be a member of the advisory committee of the U. S. Coast Guard Academy, New London, Conn. In addition, he is Chairman of the Welding Research Council of the Engineering Foundation.

Kalish Named to Olin Mathieson Post

Appointment of Herbert S. Kalish AWS as section chief, materials, was announced by the Metallurgical Laboratories of Olin Mathieson Chemical Corp. of New Haven, Conn.

H. S. Kalish

Mr. Kalish was formerly engineering manager of the Metal Fabrication and Assembly Department at Sylvania-Corning Nuclear Corp., Bayside, N. Y.

Mr. Kalish holds the B.S. Degree and Professional Degree of Metallurgical Engineer from the Missouri School of Mines. He received an M.S. Degree in Metallurgical Engineering from the University of Pennsylvania.

Crucible Advances Ferrall and Dickerson

Crucible Steel Company of America has announced the election of L. L. Ferrall as executive vice-president and J. D. Dickerson as vice-president—operations.

Mr. Ferrall was formerly vice-president—operations and Mr. Dickerson was manager of steel production.

Vice-president—operations since 1954, Mr. Ferrall joined Crucible in 1945 as director of metallurgy. He was named assistant vice-president—operations in 1953.

A native of Philadelphia, Mr. Dickerson, 48, joined Crucible as chief metallurgist at the company's Midland, Pa. Works in 1953. He was named staff assistant to the vice-president—operations in 1955 and manager of steel production in 1957.

Kuhlmann Joins Indair

Kurt Kuhlmann has been engaged as general plants superintendent of Industrial Air Products Co., Portland, Ore.

Mr. Kuhlmann is a graduate of the Institute of Technology in Berlin, Germany. He continued his post-graduate studies in physics at Columbia University in New York. Mr. Kuhlmann was formerly in the employment of the American Messer Corp., New York City.

Cordovi Joins Inco

Marcel A. Cordovi has joined the staff of the Atomic Power Developments Section of the Development and Research Division of the International Nickel Co., Inc., F. L. Laque, vice-president and manager of the division has announced.

Prior to his association with International Nickel, Mr. Cordovi served as manager of the Materials and Testing Department of the Atomic Energy Division of the Babcock and Wilcox Co., New York.

Mr. Cordovi is a United States delegate to the International Institute of Welding and is a member of several technical groups, including the Welding Research Council.

The author of numerous articles on metallurgical, nuclear and welding subjects, he has also produced the "Glossary of Foreign Welding Terms" published by the AMERICAN WELDING SOCIETY.

Harris Calorific Advances Four

Clarence M. Taylor [M], president of Harris Calorific Co., Cleveland, Ohio, has announced four executive promotions within the firm. Stevenson M. Taylor [M] assumes the office of executive vice-president. Previously in charge of staff operations for Harris, the former Cornell and Case student has been with the firm since 1956. Leigh H. Perkins [M] becomes vice-president in charge of sales, relinquishing his former position as sales manager to Roy L. Rasmussen [M]. Mr. Rasmussen has been with the Cleveland concern for 37 years. In another move, Richard M. Peck was named plant superintendant.

Clarence M. Taylor

Leigh H. Perkins

Roy L. Rasmussen

Richard M. Peck

WELDING ENGINEER

Must have experience in the fabrication of piping systems to high standards of quality. An engineering degree and five years' industrial experience are minimum requirements for this position. Nuclear experience desirable but not mandatory.

All inquiries will be held in strict confidence. Please submit complete data.

Location eastern New England.

Box V-358

METALLURGISTS

B.S. recent grads with high scholastic standing. To conduct long range research in the general field of fusion welding. These are permanent positions with a leader in the welding field. Laboratories located in suburban area of North Central New Jersey, 45 minutes from New York City. Excellent salaries, benefits, and growth potential. Submit complete resume of personal, educational and business history to

PERSONNEL MANAGER
AIR REDUCTION RES. LABS.
MURRAY HILL, NEW JERSEY

WELDING ENGINEERS

HIGH TEMPERATURES HIGH ALTITUDES

Los Angeles Division of NAA is looking for graduate engineers with at least two years experience in welding to work on hot, high-flying weapon systems and space ships such as B-70, F-108, and X-15.

If selected for one of these positions, you'll plan and coordinate applied research projects in fusion welding of materials for high temperature applications. These projects include development of design data and manufacturing problems for ultra high speed and high altitude air vehicles.

For more information please write to: Mr. C. H. Stevenson, Engineering Personnel, North American Aviation, Inc., Los Angeles 45, California.

THE LOS ANGELES DIVISION OF
NORTH AMERICAN AVIATION, INC.

WELDING RESEARCH

A Welding or Metallurgical Engineer is required for investigations into new and challenging areas of Welding and Brazing Research. Applicant should have at least a B.S. degree and several years of experience. Our opening offers the right man an unlimited opportunity for professional growth.

This is a permanent position in an expanding midwestern industrial research organization. Here is a challenging opportunity for the creative man who desires to work on challenging and diversified research programs and in addition enjoy stimulating staff associations and an unusually pleasant working climate. Receive excellent salary and employee benefits.

If you are interested in this exceptional opportunity send a complete resume to:

Box V-357,
The Welding Journal,
33 W. 39th St.,
New York 18, N. Y.

EMPLOYMENT SERVICE BULLETIN

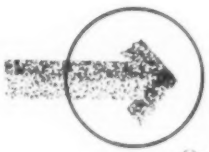
Positions Vacant

V-358. Counter man for welding supply house in South Florida. Must have excellent character, reliable and good recommendations. Excellent opportunities.

V-359. Welding Engineer wanted by leading designers, developers and manufacturers of heat-resistant alloy products. Located in Southern California. Must be familiar with the field of electronics as it pertains to the automatic controls current being adapted to fusion welding machines. Familiar with new metals and alloys and experienced in fusion possibilities, particularly with ultra-thin stainless steel.

Services Available

A-707. Sales Engineer. Age 32. Married. Veteran. Twelve years' experience in welding and sales, including oxyacetylene, arc and inert processes. Presently living in Michigan. Résumé on request.



PROCESS ENGINEERS

Outstanding opportunities with rapidly expanding company in nuclear fuels. These positions require from two to ten years experience including metal working. Metallurgical experience desirable.

Applicants who qualify will work with nuclear fuels and assemblies. Must be team men – work well with other people. Plenty of room for advancement. Liberal salary and benefits including profit sharing and pension plans.

Modern plant located in suburban Massachusetts. Easy access to Cape Cod and Narragansett Bay. Send complete resume to Mr. Andrew Staley.

M&C NUCLEAR, INC.
BOX 898, ATTLEBORO, MASSACHUSETTS

NEW LITERATURE

Combination Arc-Welding Machine

A 4-page folder, DM-71, published by Hobart Bros. Co., Troy, Ohio, describes a combination a-c, d-c and inert-gas welding machine and gives the advantages of having a unit that will do all three types of welding.

For your free copy, circle No. 20 on Reader Information Card.

The Story of Chemetron Corporation

A new brochure which describes the activities of the entire company has been published by Chemetron Corp., formerly National Cylinder Gas Co., still headquartered at 840 N. Michigan Ave., Chicago 11, Ill.

The 32-page illustrated brochure contains sections on products and services of the company's seven divisions and its subsidiaries and affiliate companies and features the first history of the company.

In a foreword Charles J. Haines, president of Chemetron, explains why the company decided to change its name and realign its organizational structure.

For your free copy, circle No. 21 on Reader Information Card.

Surfacing in Various Industries

Stoody Co., Whittier, Calif., has issued its May 1958 issue, Vol. 17, No. 6, of "Fusion Facts," the company's hard-surfacing booklet. Included in this 24-page Spring issue are seven articles on such topics as semiautomatic surfacing in highway construction, manual surfacing of posthole augers in utilities, the application of cobalt-base deposits on catalyst cleaner bits and a discussion of the new iron-powder coating for Stoody Build-Up electrodes.

For your free copy, circle No. 22 on Reader Information Card.

Colmonoy Alloy News

Volume 3, No. 3 of the May-June issue of "Colmonoy Alloy News" is now available from Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich. The 4-page folder discusses such surfacing topics as foundry sand screws and flour mill hammers. Another article describes the new Colmonoy Welder, a semiautomatic hard-surfacing unit.

For your free copy, circle No. 23 on Reader Information Card.

Silver-Alloy Data

The illustrated "Silver Alloy Issue" of Eutectic's Technical Information Digest, designed to provide technical data for production and maintenance users of high-grade silver alloys for metal-joining, is now available from the Eutectic Welding Alloys Corp., Flushing 58, N. Y.

This special 24-page issue explores the reduced costs and greater economy possible when silver alloys are correctly specified and used.

A main feature is a comparative analysis chart, listing the specific properties and uses for 11 of Eutectic's silver-bearing alloys.

For your free copy, circle No. 24 on Reader Information Card.

Air-Operated Bending Machines

Bulletin 13-093 from the Taylor-Winfield Corp., Warren, Ohio, explains a new line of air-operated tangent bending machines designed specifically to meet a need for inexpensive rapid, light-duty metal forming equipment.

These benders are useful on products requiring radius or square bends in sheet metal, extruded or tubular sections and are available in styles of single-wing, duplex and quadruplex models.

For your free copy, circle No. 25 on Reader Information Card.

Arc Welding of Titanium

A technical brochure discussing the method and techniques used in arc welding titanium has just been published by Mallory-Sharon Metals Corp., Niles, Ohio.

"Recommendations for Arc Welding Titanium" provides information on this subject, listing the various commercially pure titanium grades and titanium alloys which can be arc welded. Basic problems in handling these materials are discussed.

For your free copy, circle No. 26 on Reader Information Card.

Dye Penetrant

A 4-page folder in color, issued by Magnaflux Corp., 7300 W. Lawrence Ave., Chicago 31, Ill., describes a safety improvement in the firm's "Spotcheck" dye-penetrant inspection materials. Using a base of chlorinated-hydrocarbon solvents, the improved "Spotcheck" formulas are said to be nontoxic, although the manufacturer does advise use in reasonably ventilated areas. This penetrant is supplied in pressurized spray cans and is recommended for various uses in tools, castings, maintenance, assembly and heat treating.

For your free copy, circle No. 27 on Reader Information Card.

Supply of Nickel

Inco and United States Government accumulated stocks of unconsumed nickel on hand in North America and available to consumers at April 30, 1958, are estimated by the International Nickel Co., Inc. at 112,000,000 lb and are continuing to grow. Consumers' inventories at the same date are estimated at 32,000,000 lb. These amounts taken together (144,000,000 lb) are the equivalent of over half of the total 1957 nickel consumption in North America for both civilian and defense purposes.

These estimates are contained in a survey entitled "The Supply of Nickel—1958-1961," prepared by the International Nickel Co., Inc., 67 Wall St., New York 5, N. Y., to provide nickel users with up-to-date information on nickel supplies and outlook.

For your free copy, circle No. 28 on Reader Information Card.

Safety

The National Safety Council, 425 N. Michigan Ave., Chicago, 11, Ill., has two new publications available for industry—one for employes, the other for foremen.

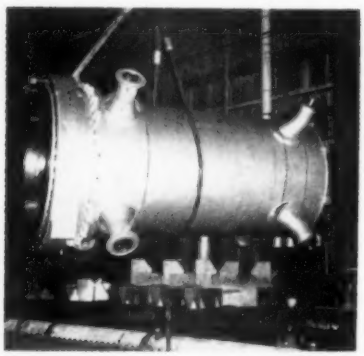
The publications, "Rules for Safety" and Book 8 in a series of "Five Minute Safety Talks for Foremen," are designed to promote safety in industry.

"Rules for Safety," the Council says, is the "biggest and best safety rules' booklet ever compiled—40 pages covering accident prevention do's and don'ts, how's and why's." The booklet gives safety rules for using power tools, stacking material and lifting and carrying.

The book of safety talks for foremen is a compilation of talks that appeared in earlier books in the series.

For your free copy, circle No. 29 on Reader Information Card.

WELDED REACTOR VESSEL



This giant 100-ton pressure vessel was welded at Foster-Wheeler's Mountaintop, Pa. plant by the automatic submerged-arc process and all pressure welds were examined by X-ray. The stainless-steel cladding on the vessel flange was deposited by a special automatic weld-cladding process. The unit is for the prototype nuclear propulsion plant of the nation's first atomic-powered surface ship

Fittings and Flanges

A new folder has been released by the Tubular Products division of The Babcock & Wilcox Co., Beaver Falls, Pa. This folder, known as Bulletin FB-504, explains economical methods for ordering seamless welding fittings and forged steel flanges which are produced to close dimensional tolerances.

For your free copy, circle No. 30 on Reader Information Card.

Stainless Steel

Complete details on the machining, welding and heat treating of cast corrosion and heat-resistant high alloys are now available from the Alloy Casting Institute, Mineola, N. Y. The six-page folder gives specific numerical data for each of 14 cast corrosion-resistant alloys, and for 14 cast heat-resistant alloys.

For your free copy, circle No. 31 on Reader Information Card.

Spot Welding Inconel X

Bulletin SP-20 from the Taylor-Winfield Corp., Warren, Ohio, gives recommended welding schedules for spot welding Inconel "X" in thicknesses of 0.032 to 0.188 in. The paper was presented at the 39th AWS Annual Spring Meeting at St. Louis in April and was prepared by Jean Harris, welding engineer, and J. J. Riley, chief electrical engineer, The Taylor-Winfield Corp.; and M. D. Bellware, Research and Development Division, International Nickel Co.

For your free copy, circle No. 32 on Reader Information Card.

Welding Goggles

New M-S-A "softsides welder's goggles," and M-S-A "softsides goggles" that provide protection against chemical splash, are described in a reference-styled, 8½ - by 11- in. size bulletin just published by Mine Safety Appliances Co., 201 N. Braddock Ave., Pittsburgh 8, Pa.

The Softsides Goggles, with frames of soft vinyl, are designed for improved ventilation and wearing comfort, better protection, broader vision and for use over conventional prescription glasses.

The new bulletin lists catalog numbers for each of three models of the M-S-A "softsides welder's goggles" and unit and replacement parts for the M-S-A "softsides goggles."

For your free copy, circle No. 33 on Reader Information Card.

New Clarkson Products
FOR WELDERS

WELD-GARD

STOPS WELD SPATTER

prevents adhesion of weld spatter to metal
non-toxic, non-inflammable, non-corrosive
apply with brush
spatter is wiped off without marring finish

DEOXALUM

CLEANS AND DEOXIDIZES ALUMINUM FOR BETTER WELDS

a brush-on • wipe-off cleaner
one application removes both organic and oxide contaminants
provides clean, low electrical resistant surfaces

Send for complete information and samples.

Clarco

The Clarkson Laboratories, Inc.
930 N. Darien St., Philadelphia 23, Pa.
Welding Supply Dealers: dealers needed in some areas.

For details, circle No. 34 on Reader Information Card

Seminar on
RESIDUAL STRESSES

- What Are They?
- How Do They Get There?
- Are They Dangerous?
- How Can You Get Rid of Them?

Prof. R. Weck of Cambridge University and Director of the British Welding Research Association, will be brought to America this October to deliver seven important lectures on residual stresses. Coupled with these outstanding lectures will be seven discussion periods by 14 American experts.

This Seminar will be held during the latter part of Metal Show Week

October 30, 31 and November 1, 1958

Place: Wade Park Manor, Cleveland

Registration Fee: Including lunches and dinners for the three days, $150.00. (Early registration with $25 deposit suggested)

Mail your reservation now—or write for folder giving complete details of this important ASM Metallurgical Seminar to

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For details, circle No. 35 on Reader Information Card

Tube Turns announces **NEW SAFEGUARD FOR ALLOY PIPING**

For details, turn the page . . .

NOW ...individual packaging protects each TUBE-TURN Alloy Welding Fitting and Flange

AVAILABLE IN...

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ALUMINUM ALLOYS	SILICON BRONZE
NICKEL	RED BRASS
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HASTELLOY B & C	ZIRCONIUM
	ZIRCALOY

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on TUBE-TURN Alloy Fittings and Flanges

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Please send me bulletins on these fittings and flanges:

☐ Alloys ☐ Stainless Steel ☐ Aluminum

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Your nearby Tube Turns' Distributor can supply your fitting needs in alloys and non-ferrous metals . . . as well as in carbon steel, wrought iron, carbon-moly and chrome-moly. This one source for all your requirements in welding fittings and flanges enables you to simplify purchasing and cut red tape.

Tube Turns is now safeguarding the top quality of its stainless steel, aluminum and other alloy products with individual packaging. All of these fittings in sizes through 12", and flanges through 8", are now wrapped in kraft paper and individually packaged in a rugged container, built to standards established by extensive testing. Hence, from point of rigid inspection to job site, *each* fitting is *protected* against damage.

Here is new *convenience*, too. Your fittings are easier to store. And each container is fully marked with description of fitting or flange, size, schedule, type material and production lot for positive, easy identification in the warehouse or on the job.

Here is another plus value you get when you specify TUBE-TURN* Alloy Fittings and Flanges, and buy them from your nearby Tube Turns' Distributor.

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CHEMETRON

Code Summary

The Tubular Products Division of the Babcock & Wilcox Co., Beaver Falls, Pa., has published a 48-page pressure-temperature bulletin which correlates and summarizes the various pressure piping and boiler and pressure-vessel code specifications. The bulletin reportedly permits the solving of equations of minimum or nominal wall thickness, maximum allowable working pressure and/or allowable working stress.

For your free copy, circle No. 36 on Reader Information Card.

X-Ray Booklet

A 12-page booklet entitled "X-ray Analysis Theory & Instrumentation" is available from the Instruments Division, Phillips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

The text covers principles of operation and uses simple diagrams to illustrate the basic differences between: film diffraction, diffractometry and spectrography.

Subjects discussed include: basic diffraction unit, Bragg's law, diffractometer, wide range goniometer, electronic circuit panel, counting rate computer, spectograph assembly, scintillation, proportional and flow-proportional detectors, and Geiger tubes.

For your free copy, circle No. 37 on Reader Information Card.

Induction Heaters

A 4-page illustrated brochure, describing high-frequency induction heaters has been published by L. C. Miller Co., 5005 E. Slauson Ave., Los Angeles 22, Calif.

The product, trade-named Miller Re-Coil, is said to facilitate the replacement of work coils. According to the manufacturer, the Miller Re-Coil is adaptable to all makes of induction heaters in use today.

For your free copy, circle No. 38 on Reader Information Card.

Mechanical Presses

An 8-page bulletin issued by the Federal Machine and Welder Co., Warren, Ohio, features single-action, straight-side and single-crank mechanical presses in capacities from 60 to 400 tons.

For your free copy, circle No. 39 on Reader Information Card.

Gas-Producing Plants

Rectification plants for the production of oxygen and/or nitrogen in liquid or gaseous form are described in a catalog just issued by Superior Air Products Co., 132 Malvern St., Newark 5, N. J. Station pumps with vaporizers and storage and converter tanks for liquid oxygen, hydrogen and argon are also illustrated and described. Technical data are included.

For your free copy, circle No. 40 on Reader Information Card.

Automatic and Semiautomatic Arc-Welding Machines

Bulletin DM-73, released by Hobart Bros. Co., Troy, Ohio, discusses all types of automatic and semiautomatic welding equipment and covers power sources, wire feed mechanisms, guns, heads and controls for submerged-arc and inert-gas-shielded arc welding.

For your free copy, circle No. 41 on Reader Information Card.

Welding Equipment

Two new NCG products that are said to provide increased versatility and work-area mobility in semiautomatic welding—a crane-held cage assembly to carry control and wire-feed unit, and a welding equipment carrier-cart with telescoping boom for control and wire-feed unit—are described in Bulletin NH-138 issued by the National Cylinder Gas Division of Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill.

For your free copy, circle No. 42 on Reader Information Card.

Comparison Chart

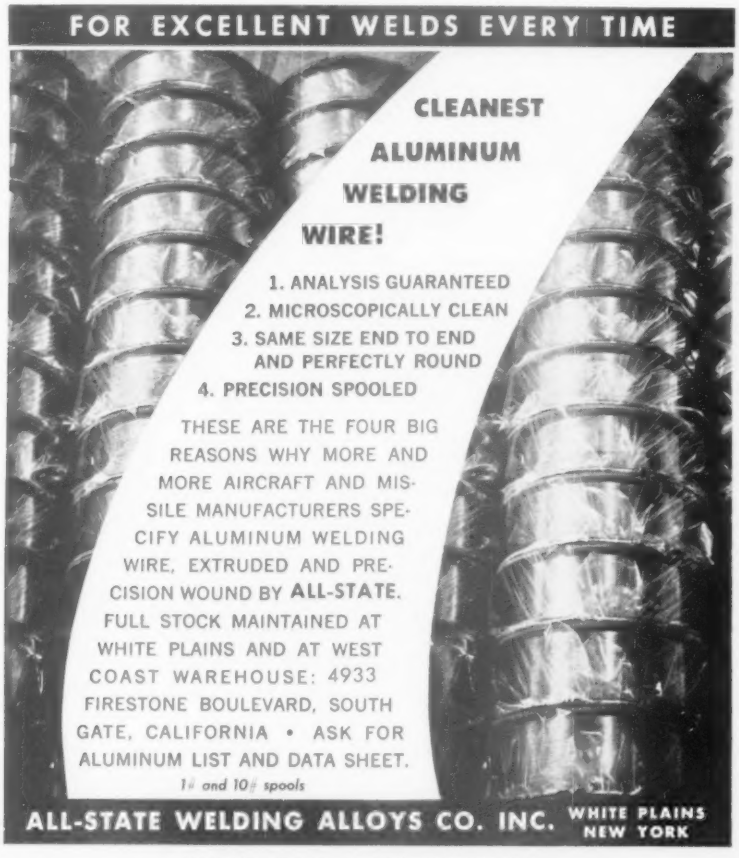
A reference chart from the American Brazing Alloys Co., P. O. Box 11 in Pelham, N. Y., lists numerically the entire Ambraze line and its comparison of alloy numbers to the two other leading lines of brazing alloys. The chart allows the buyer or user to cross reference an Ambraze number at a glance.

For your free copy, circle No. 43 on Reader Information Card.

Zirconium and Hafnium

A new 16-page brochure, "Technical and Application Data on Zirconium and Hafnium," has just been published by Mallory-Sharon Metals Corp., Niles, Ohio.

The booklet reviews steps in the production of zirconium from raw material to finished mill products in the Ohio plants of the world's largest integrated producer of reactive metals. An illustrated discussion of the basic refining processes is also included.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1# and 10# spools
ALL-STATE WELDING ALLOYS CO. INC.
WHITE PLAINS NEW YORK
For details, circle No. 44 on Reader Information Card

For details, circle No. 99 on Reader Information Card

The brochure discusses the properties of both zirconium and hafnium in nuclear-reactor applications and a table illustrates the neutron capture characteristics of a number of metals.

For your free copy, circle No. 45 on Reader Information Card.

Electronic Line Tracer

The National Cylinder Gas Division of Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill., has published a booklet, N-142, which describes the NCG "Electronic Line Tracer" for shape-cutting machines. The 7-page booklet covers such factors as construction, principle of operation and detailed operation of the electronic tracing head. Schematic drawings and photographs are included.

For your free copy, circle No. 46 on Reader Information Card.

Weld Screws

A 4-page folder from the Parker-Kalon Division of the General Transportation Corp., Clifton, N. J., illustrates and describes the two basic types of "P-K Rimguard" weld screws for use in resistance welding. Both models incorporate in their structures a rim around the periphery of the weld screw which limits to a predetermined degree the amount of pressure applicable to the projections during the fusing stage. Type WS-T weld screw provides its projections on the top of the head, while the projections on Type WS-U are found on the bottom.

For your free copy, circle No. 47 on Reader Information Card.

REVIEWS
OF NEW BOOKS

Titanium

Symposium on Titanium (STP No. 20), 214 pages, 6 by 9 in. Hard cover. Price $4.75. Published by American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Aside from uranium, probably no metal in the past decade has so captured the interest of the metallurgical industry as titanium. It is a good metal, with a combination of availability, lightness with strength and corrosion resistance that makes it of particular interest to the aeronautical industry. This interest, with support from the Department of Defense, has resulted in phenomenal progress in the commercial and technical development of this relatively new metal of construction.

This symposium brings together 14 papers designed to give good technical information on which to base specifications. These papers pertain primarily to property evaluation. The symposium was originally presented during the 2nd Pacific Area National Meeting, Los Angeles, Calif., and sponsored by Committee B-2 on Non-Ferrous Metals and Alloys. The book is illustrated and many of the papers contain references.

Elevated-Temperature Data of Welds

Elevated Temperature Properties of Weld Deposits and Weldments—STP 226, 228 pages. Paper cover, 8½ × 11 in., $5.50. Published by the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

This publication attempts to draw together the available elevated-temperature data on steels and similar alloys as presented by current good welding practice.

Among the materials covered are: welded carbon steel, welded chromium-molybdenum steel, welded stainless steels and superstrength alloys. In all, data are presented for 30 varieties of steel welds. Some of the data given for each are: short-time tensile properties, creep and rupture strength and chemical composition.

This report is one of a current series of ASTM Special Technical Publications summarizing properties of alloys at high temperatures. These are prepared under the auspices of the Data and Publications Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals.

Nuclear Reactor Materials

Radiation Effects on Materials Vol. II—STP 220. 140 pages. Hard cover, 6 × 9 in., $3.75. Published by American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

This is the second of a series of symposiums on Radiation Effects on Materials sponsored jointly by ASTM and the Atomic Industrial Forum. The data and evaluations presented are made as a contribution to the understanding of existing code and specification values as they apply to nuclear reactor structures and components. The known properties of materials must be evaluated in the light of the actual reactor operating conditions. By adapting and interpreting the vast backlog of data on unirradiated materials with the sparse but accumulating knowledge of irradiated materials, it is stated that cautious extrapolation within the limits of experimental work can be allowed.

This symposium will be of especial value to those interested in the design and operation of nuclear reactors. This volume is well illustrated. The papers are:

Introduction—G. D. Calkins and C. C. Woolsey.

Selection of Structural Materials for Components of Nuclear Power Plants—W. L. Fleischmann.

Problems in Standardization of Techniques in Radiation Effects Studies—M. J. Feldman and R. H. Fillnow.

Application of the Battelle Research Reactor to Radiation Effects Studies—J. W. Chastain.

A Technique for Measurement of Electrical Resistivity of Radioactive Metals—C. L. Boyd.

Techniques of Tension Testing Irradiated Materials at Elevated Temperatures at Hanford—W. S. Kelly, D. C. Kaulitz and R. E. Hueschen.

Techniques for Making Visual Examinations and Dimensional Measurements at Hanford's Radiometallurgy Laboratory—D. L. Zimmerman.

Hanford's Improved Remote Metallographic Equipment—J. R. Morgan.

Effect of Heat Treatment and Burnup on Radiation Stability of 10 per cent by Weight Molybdenum-Uranium Fuel Alloys—G. D. Calkins, J. L. Gates, F. A. Rough, D. O. Leeser, and A. DelGrosso.

Engineering Effects of Radiation on Nuclear Fuels—B. Lustman.

A Survey of the Radiation Stability of Hydrocarbon Fuels—J. G. Carroll, R. O. Bolt and J. A. Bert.

Selection of Organic Materials as Reactor Coolant-Moderators—E. L. Colichman and R. H. J. Gercke.

Effects of Radiation on Electronic Components—I. Semiconductor Devices—M. A. Xavier, S. Nelson, A. Yofsky, A. Walters and G. J. Rotariu.

Farm Welding

Farm Welding, third edition, by Marvin M. Parker, shop instructor, Hayti Consolidated Schools, Hayti, Mo. 262 pages. 179 illustrations, 6 by 9 in. Price $5.40. Published by McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York, N. Y.

This particular edition is divided into three general sections, metals and welding, are welding and oxyacetylene welding and cutting. The text is designed to give vocational agricultural students and farmers practical information on welding and its use on the farm. Explanation is given of basic principles while emphasis is placed on correct welding procedures. The author has made a special effort to anticipate the difficulties commonly encountered by the inexperienced welder and to provide methods for avoiding these difficulties.

MUREX® gives you more for STAINLESS

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For details, circle No. 48 on Reader Information Card

NEW PRODUCTS

Aluminum Arc-Welding Electrodes

Two aluminum electrodes for flat and vertical welding (d-c reverse polarity) on cast, drawn and sheet aluminum are announced by All-State Welding Alloys Co., Inc., 249-55 Ferris Ave., White Plains, N. Y.

One designated E-43 is for work wherever 5% silicon aluminum-Type 4043- is used. The other, E-2, is for pure aluminum, Type 1100.

E-43 and E-2 electrodes are made from the same All-State superclean extruded wire as used in the company's large production of precision spooled aluminum for inert-arc welding.

For more details, circle No. 49 on Reader Information Card.

Upgraded Ratings on Welding Flanges

New ratings of its lightweight forged steel taper face welding neck flanges were announced by Tube Turns Division of Chemetron Corp., Louisville, Ky.

On the basis of fatigue and bending tests under simultaneous pressure, the flange is now recommended for 175 psi liquid, gas or air service at 150° F. Originally the flange was rated at 125 psi WOG (water, oil and gas). It is now rated suitable for 125 psi dry saturated steam at 353° F.

The flange, on which a patent is pending, was introduced by Tube Turns less than two years ago. Dimensions match cast-iron flanges and valves having Class 125 flanges in accordance with ASA B16.1.

For more details, circle No. 50 on Reader Information Card.

Iron-Powder E-6012 Electrode

The Lincoln Electric Co. of Cleveland, Ohio, has announced a new E-6012 electrode. Lincoln states that the design of the electrode coating, which includes the addition of iron powder, makes the electrode easier to operate and faster than previous E-6012 designs. The electrode, Fleetweld 7MP, is classed as an all-position, a-c and d-c, mild-steel electrode.

The electrode is available in $\frac{1}{8}$, $\frac{5}{32}$ and $\frac{3}{16}$-in. diam.

For more details, circle No. 51 on Reader Information Card.

Welding Cable Device

A new device for holding welding cable or gas hose, especially when working above the level of the power source, as in the erection of structural steel, is marketed by Jackson Products, subsidiary of Air Reduction Sales Co., Warren, Mich.

Called "Cablehitch," it reportedly cuts down the welder's fatigue, and promotes his safety and efficiency. It is also said to save wear on the cable and the cable connections.

For more details, circle No. 52 on Reader Information Card.

Improved Torch Control

A new type welding torch, the Levermatic, has been developed by Dockson Corp., 3839 Wabash, Detroit, Mich. The Levermatic is especially engineered

to improve the efficiency and comfort of the operator.

Fuel flow is controlled in the conventional manner, by light pressure on a thumb lever, from pilot flame to work adjustment where the lever locks in position relieving the operator of the cramping tension usually necessary to hold his flame at work heat.

The Levermatic is made in three models for light or medium welding.

For more details, circle No. 53 on Reader Information Card.

Induction-Heating Generator

Folder DM-74 from Hobart Bros. Co., Troy, Ohio, describes a 400-cycle induction-heating generator and its method of preheating and stress relieving arc-welded joints. The generator, which supplies 400-cycle ac to a wire induction-heating coil, is automatically operated by an Electronik strip chart program controller. Any planned program of preheating, soaking and cooling is automatically controlled and a permanent record of every phase of the program is recorded on a strip chart.

For more details, circle No. 54 on Reader Information Card.

Portable Radiography Unit

The lightest, highest voltage and least expensive per kvp portable X-ray unit available today for field and plant radiography are the claims made for the new General Electric LX-140.

Model LX-140 X-ray unit, manufactured by General Electric Co., 1855 W. Electric Ave., Milwaukee 1, Wis., is said to offer effective radiation protection, unitized design, simplified controls, dust and moisture proof head, in addition to

being the lightest portable unit with the highest voltage per pound.

Designed to resist the roughest of handling expected of an X-ray unit of this type, the new LX-140 offers a continuous range from 70 to 140 kvp. Radiographs with 2% sensitivity and 1.5 density can be produced with a 1½-min exposure through 1¼ in. of steel, according to General Electric.

For more details, circle No. 55 on Reader Information Card.

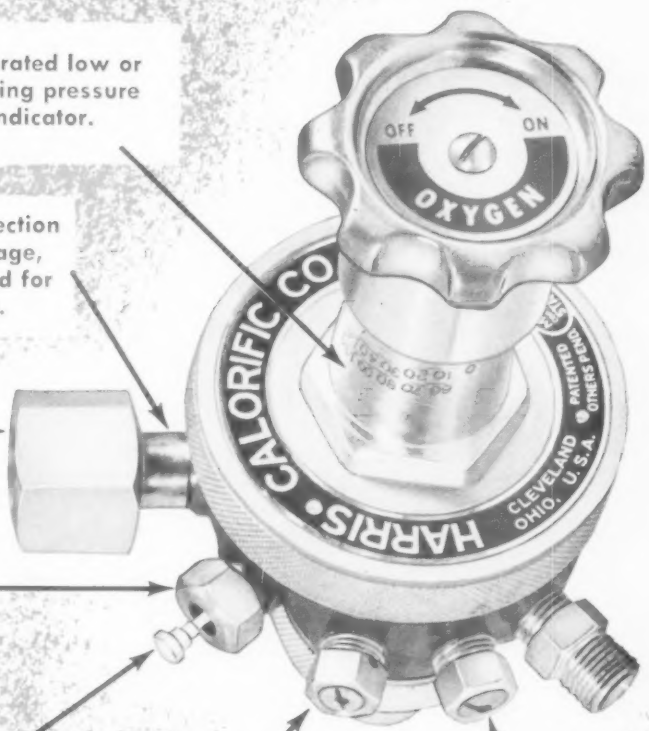
Noise Reducing Helmet

American Optical Co., Safety Products Div., Southbridge Mass., announces a combination welding helmet-sound protector for use in areas where there is exceptional noise.

HERE'S THE NEW

HARRIS GAUGELESS REGULATOR

Model 77 (oxygen) · Model 77P and 77D (acetylene)



Calibrated low or working pressure indicator.

Short inlet connection reduces breakage, readily removed for replacement.

Nut supported over inlet stem to prevent damage to stem seat.

High pressure cylinder content indicator.

Indicator showing full pressure.

Intermediate pressure safety valve.

Working pressure safety valve.

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For details, circle No. 56 on Reader Information Card

New
TAPPING TEE
FOR GAS MAINS
by Nibco

PART NO. 4911 - GS
Made from Schedule 40 ASTM A-106 A or B carbon steel

- *WELDS TO MAIN AND 1-1/4" SUPPLY LINE*
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- *EXTRA STRONG, EXTRA SMOOTH INSIDE AND OUT*
- *COMPLETE WITH PLUG AND CAP*

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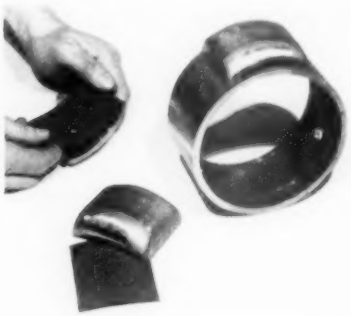
For details, circle No. 57 on Reader Information Card

The sound protection within the fiber glass helmet is furnished by elongated-type ear domes which cover the jawbone aperture. Vinyl sponge ear seals are said to fit securely even when worn over personal or safety glasses. The ear puffs are easily removable and replaceable for sterilization.

For more details, circle No. 58 on Reader Information Card.

Brazing Alloys in Sheet Form

Nicrobraz brazing alloys are now available in flexible sheet stock, according to an announcement from Stainless Processing Division of Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich. The new material, available in flexible sheets from 0.015 to 0.060 in. thick, is recommended for use in brazed laminated sections and sandwich configurations of stainless steels, high alloys and titanium.



For more details, circle No. 59 on Reader Information Card.

Brazing Rod

American Brazing Alloys Co., P. O. Box 11, Pelham, N. Y., announces the availability of Ambraze No. 111 high-tensile nickel-silver brazing rod for the fabrication of small parts, and the repair of machine tools. Manufactured in bare and flux-coated rod forms, they can, reportedly, be used in place of silver solders. Also, they are said to offer higher strength when more heat is permissible.

For more details, circle No. 60 on Reader Information Card.

Air Hoist

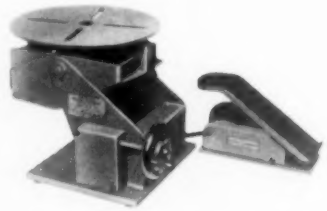
Shaw-Box Crane & Hoist Division of Manning, Maxwell & Moore, Inc., Muskegon, Mich., have just announced for sale a new line of air hoists. Known as "Budgit" Air Hoists, they are available in either link or roller chain types in ½-, 1-, and 1-ton capacities and are developed especially for production lifting jobs.

Contained in these new hoists are such features as frames made from aluminum alloy; alloy steel heat-treated gearing with machine shaved teeth; adjusted load brake; built-in muffler; one-hand pendant cord control; and upper and lower safety hooks made of steel forgings.

For more details, circle No. 61 on Reader Information Card.

Welding Positioner

Raco Engineering Service, 2116 Chestnut Ave., Alhambra, Calif., has developed Model RA-100 welding positioner for use with manual or automatic welding. Capacity of the unit is



100 lb. The 75-lb positioner contains a variable-speed drive system, a 12-in. diam turntable, and provides reported rpm ranges of 0 to 1.41 and 0 to 10.5 for manual and automatic welding, respectively.

For more details, circle No. 62 on Reader Information Card.

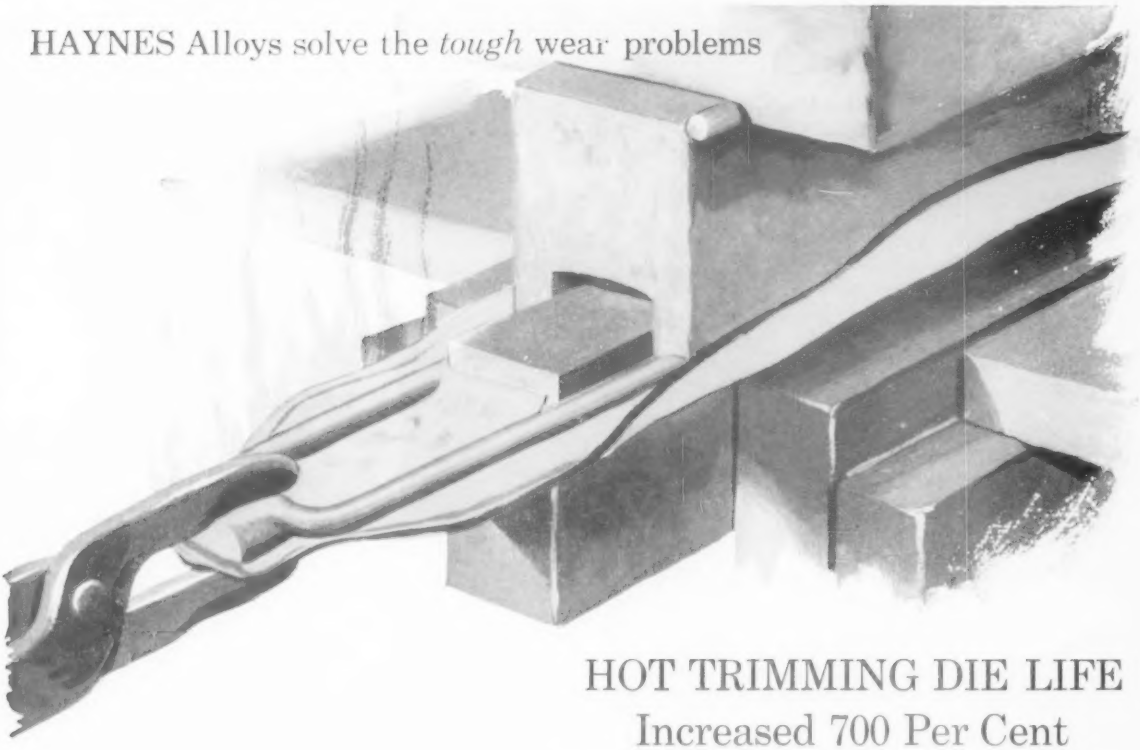
Liquid Flux

A new organic, liquid flux for soldering copper alloys and tinned metals with residue guaranteed to be absolutely inert and corrosion-free has been developed by the Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, N.Y.

Called EutecSol (R) Neutral Flux 808, it is formulated for lead-tin soldering applications mainly in the radio, television and electronics industries. These include general purpose wiring, printed circuitry, joining to etched circuit boards, tinning leads and sealing.

The new development is suited for solders melting below 500° F. It can be used to join plated and clad metals

HAYNES Alloys solve the *tough* wear problems



HOT TRIMMING DIE LIFE
Increased 700 Per Cent

HAYNES hard-facing alloys resist the sudden shock of impact and the softening effects of heat . . . two characteristics that make them unusually successful in extending the service life of hot-working equipment. In one plant, hot-trimming dies hard-faced with a HAYNES cobalt-base alloy removed the flash from 25,000 parts before they had to be reconditioned. This was a 700 per cent increase in service life over unprotected dies. In this instance the parts were heated to 2000 deg. F just prior to the trimming operation.

If you have a problem involving a combination of heat and impact, straight abrasion, or corrosion, you will find that there is a HAYNES hard-facing alloy that can solve it . . . economically. The hard-facing deposit will increase the service life of the part and, because of its superior wearing qualities, permit you to use a less expensive base material.

Write for literature or call one of our sales offices. HAYNES STELLITE COMPANY, Division of Union Carbide Corporation, Kokomo, Indiana. Sales offices in Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, San Francisco.

This trimmer die, being touched up with a HAYNES nickel-base alloy, has trimmed over 20,000 parts. The hard-facing alloy is tough, machinable, and can be applied to all common die steels by the metallic-arc process.

HAYNES
ALLOYS
HAYNES STELLITE COMPANY
Division of Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

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For details, circle No. 63 on Reader Information Card

such as terne plate, tin plate, as well as metals flashed with copper or specialized coatings.

For more details, circle No. 64 on Reader Information Card.

Press Feed Unit

A new press feed arrangement, known as Flexofeed, developed by research engineers of Precision Welder & Flexopress Corp., 3520 Ibsen, Cincinnati, Ohio, reportedly hitch-feeds material

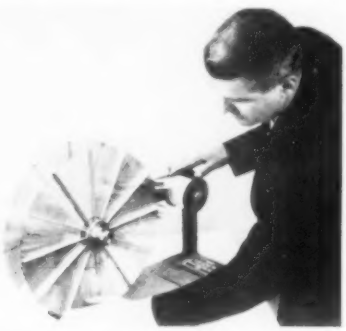
at 2200 to 2500 ipm, with accuracy to ±0.002 in. This permits high speed stamping of parts with long as well as short feed increments, from coil stock.

According to the manufacturer, feed strokes up to 36 in. are entirely feasible by the new method. Formerly, accurate stock advancement has been limited to about 1200 ipm.

For more details, circle No. 65 on Reader Information Card.

X-Ray Film

According to Picker X-Ray Corp., 25 S. Broadway, White Plains, N. Y., the problem of developing the long strips of 70 mm X-ray film used for radiographing circumferential welds in large pressure vessels can be solved by



the Nikor Film Processing Equipment. It will reportedly handle any length of film up to 100 ft.

The stainless-steel Nikor setup includes: (1) a reel to hold the film, (2) a jig to load the film onto the reel, and (3) three solution tanks.

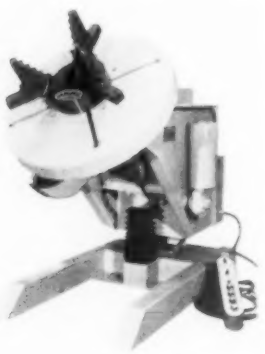
To develop the film, the loaded reel is taken from the jig, placed in the tank of developer and put on the cover. The open framing of the reel lets the developer glow freely around the film.

After the film is developed, a quick rinse is given in the washing tank and then placed in the fixing tank. When the fixing is done, the reel is returned to the washing tank for a thorough wash.

For more details, circle No. 66 on Reader Information Card.

3000-Lb Capacity Welding Positioner

Pandjiris Weldment Co., 5151 Northrup Ave., St. Louis 10, Mo., announces the development of a new 3000-lb capacity "Human" welding positioner that "thinks for the operator."



The rotation drive and controls designed into this positioner permit the operator to set the rotative welding speed in "ipm" to the desired value. Table speed, workpiece diameter and welding speed are the three variables which this control system is reported to correlate automatically.

For more details, circle No. 67 on Reader Information Card.

Liquid Flux

A liquid flux known as Eutec-Liquitor, has been developed for brazing silver, gold and platinum by Eutectic Welding Alloys Corp., 10-40 172nd St., Flushing, N. Y.

Designed mainly for critical and delicate work, Eutec-Liquitor can be applied with pipette, eye dropper, hypodermic needle, as well as automatic metering devices. This ability is said to be valuable when joining small pins, clasps, and fine wire, tubing, bellows, springs and other heat-sensitive objects.

For more details, circle No. 68 on Reader Information Card.

THEY LOOK ALIKE...

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. . . AND INSIDE ACETYLENE CYLINDERS THE BIG DIFFERENCE IS COYNE'S NEW, FASTER-FILLING, MORE ABSORBENT FILLER. LET US PROVE YOU'LL START SAVING WHEN YOU START USING COYNE ACETYLENE CYLINDERS.

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24 COMMERCE STREET, NEWARK, N. J.

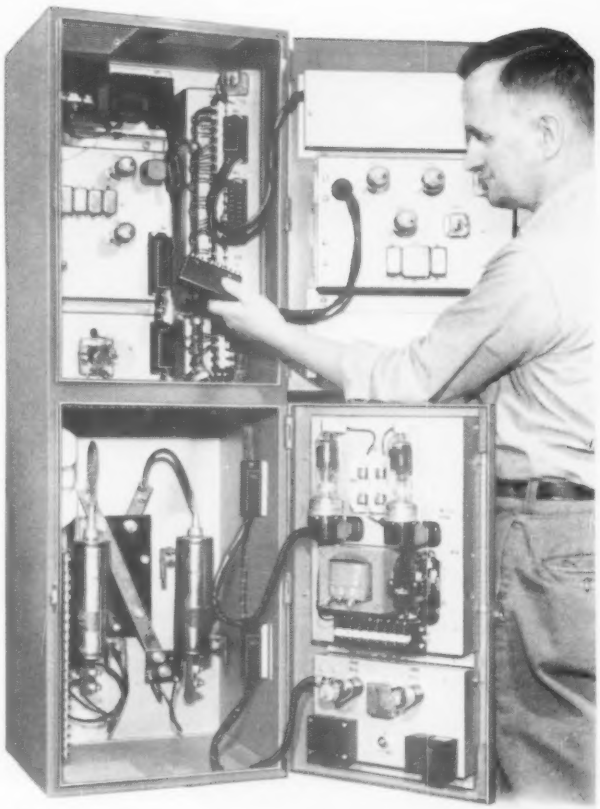
For details, circle No. 69 on Reader Information Card

This New **PLUG-IN** Welder Control

Lets You

ADD CONTROL FUNCTIONS AS YOU NEED THEM

A Wide Range of Plug-In Units Enables You to Add Components as Your Welding Jobs Change



HERE'S HOW YOU CHANGE YOUR BASIC CONTROL SIMPLY BY ADDING PLUG-IN UNITS

FOR WELDING MILD STEEL— BASIC CONTROL INCLUDES THESE PLUG-IN UNITS:

3B Timer
Relay Valve Control
Tube Firing Panel

FOR WELDING ALUMINUM— YOU ALREADY HAVE:

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Tube Firing Panel

YOU ADD THESE PLUG-IN UNITS:

Heat Control
Up-down Slope
Forge Delay

Every feature you want —for every welding job

- 22 standard units provide "custom" control for every welding requirement
- all units are plug-in type for quick change
- available in "all electronic" or "relay firing" versions
- auxiliaries for all conventional welding functions
- circuits include the latest safety features

Write for Bulletin SM-277 to Square D Company, 4041 N. Richards St., Milwaukee 12, Wisconsin

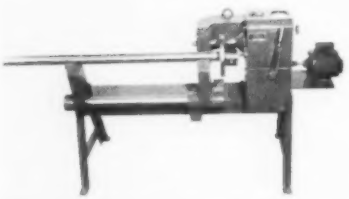
EC&M HEAVY INDUSTRY ELECTRICAL EQUIPMENT...NOW A PART OF THE SQUARE D LINE

SQUARE D COMPANY

For details, circle No. 70 on Reader Information Card

Brinell Tester

A Brinell testing machine for production testing of flange members on long shafts, such as axle assemblies, has been built by Detroit Testing Machine Co., 9390 Grinnell Ave., Detroit 13, Mich.



Hydraulically powered, it carries two dials, one showing load applied (in kilograms), and the other a direct reading dial for comparative checking, using hand-set high and low limit indicating needles.

For more details, circle No. 71 on Reader Information Card.

Welding Torch

A welding torch has been developed by the Controlled Atmosphere department of the Scientific Engineering Laboratory, 2229 McGee Ave., Berkeley 3, Calif., for the fabrication of such metals as titanium, zirconium, molybdenum and beryllium.

The new torch can be used in such applications as inert-gas-shielded tungsten- and metal-arc welding and cold-wire feed welding.

For more details, circle No. 72 on Reader Information Card.

Pressure Welder

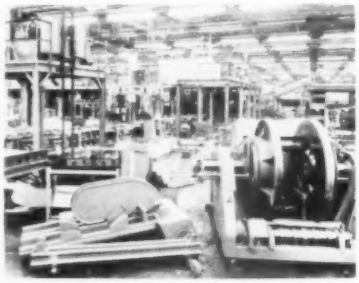
Production of a new integral hydraulic weld head and cabinet welder is announced by Vacuum Tube Products Co., 2020 Short St., Oceanside, Calif. Varied uses include welding aircraft components, electronic tubes and components, jewelry and light-gage metals.

The new unit is a standard Vacuum Tube Products welding cabinet enclosure, complete with a 2.5-kva welding transformer, integral hydraulic weld head and a wide choice of welding controls. A feature of the unit is the foot pedal hydraulic actuator, making possible immediate operation without additional mechanical connections. The unit also provides a low inertia movement, with a very accurate and easily adjusted automatic weld firing pressure, ranging from 0.5 to 100 lb.

For more details, circle No. 73 on Reader Information Card.

Resistance-Welding Production

A new L-shaped automated welding line that produces 500 complete automotive floor-pan assemblies per hour has been designed and built by the Welding and Automation Machine Divisions, Expert Die and Tool Co., Inc., 17144 Mt. Elliott Ave., Detroit 12, Mich.



This automated welding line consists of two separate lines which intersect each other to form an L-shaped floor layout. One line, called the ladder line, consists of six stations and completely fabricates the floor-pan reinforcing member with 48 resistance-welding operations. The other line, called the main line, consists of six working stations and welds the reinforcing member to the floor pan with 320 spot-welding operations.

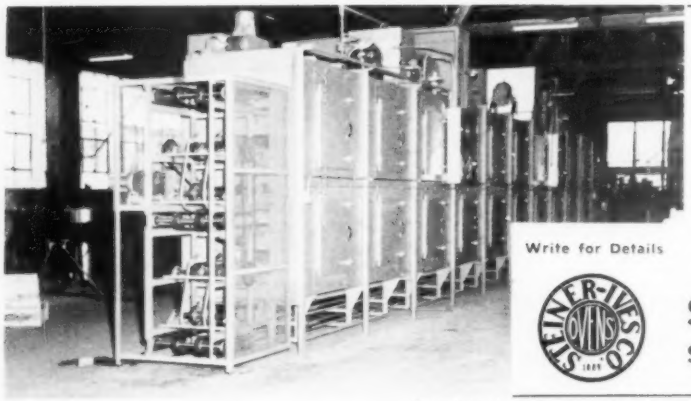
For more details, circle No. 74 on Reader Information Card.

Arc-Time Meter

A new type of arc time meter, called the "Arc-Timer," has been announced by the Machinery & Welder Corp., 700 S. Spring Ave., St. Louis, Mo. The unit is designed to facilitate machine performance analysis, operator duty cycle and time and motion studies. According

to the manufacturer, the "Arc-Timer" will accurately record the duration of arc of any welding machine, ac or dc, whose open circuit voltage does not exceed 110 v. The meter is cumulative so that arc operation between 15 and 45 v may be recorded by job, hour, week or any prescribed period.

For more details, circle No. 75 on Reader Information Card.



Conveyor oven designed to bake special flux coatings on various diameter and length welding rods for large midwest manufacturer. Recent changes in rod alloy have caused additional higher than previous, oven temperatures to be required. Unit embodies two independently operated gas fired ovens for operation to 1000°F. Ovens have two passes each and a fifth pass for cooling before packaging. Complete ovens, including humidity, temperature and safety controls are engineered at

Write for Details

STEINER-IVES COMPANY

Springfield Road . . . . Union, N. J.

For details, circle No. 76 on Reader Information Card

Telescoping Boom

A compact carrier-cart with telescoping boom to move welding control and wire-feed unit to the weld area has been introduced by the National Cylinder Gas Division of Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill.

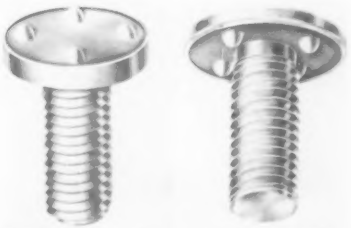
As described by NCG, the boom can be adjusted to heights from 4 to 14 ft and rotated 360 deg, providing welding flexibility for large maintenance operations and shops with limited crane service.

The hand-propelled cart, mounted on three balloon-type tires, can carry welder, water coolant unit and two standard cylinders. It is designed to move equipment necessary for NCG Dual Shield or Argonaire welding processes.

For more details, circle No. 77 on Reader Information Card.

Projection-Weld Screw

A new projection-weld screw, known as "Ringuard," is available from the Parker-Kalon Division, General American Transportation Corp., Clifton, N. J.



RIMGUARD TYPE WS-T RIMGUARD TYPE WS-U

The weld screw contains a strong protective rim around the periphery of its head and four weld projections. According to Parker-Kalon, "spatter" and "flash" are minimized by a predetermined amount of pressure applied by the rim. Less current flow is said to be needed due to the size of the four projections and the area of contact.

For more details, circle No. 78 on Reader Information Card.

Hose Clamp

According to Circle Clamp Corp., 39 Broadway, New York, N. Y., the O-shaped, one-piece clamps manufactured by the company provide rapid application without the use of special tools; compact, space-saving installation in remote areas; holding strength well in excess of hose-bursting pressures; and simplified maintenance on production equipment. The clamp is slipped into place by squeezing the parallel sides of the lugs together with ordinary pincers.

For more details, circle No. 79 on Reader Information Card.

SURVEY RESULT #1*

98% of Welding Journal readers read the Journal REGULARLY!

If proof were needed to establish the acceptance of the Welding Journal, this first Survey Result supplies it in ample measure. What is the appeal of the Journal – why so high a degree of readership? Because the Journal supplies the basic ingredients of the industry: authenticity, diversity, pride of profession – **plus** a nation-wide group of welding reporters who keep the Journal informed of people in welding. Through the American Welding Society, the Journal reaches those who are **most influential** in buying and specifying welding equipment and related products. The best buy in the welding field – price-wise, result-wise.

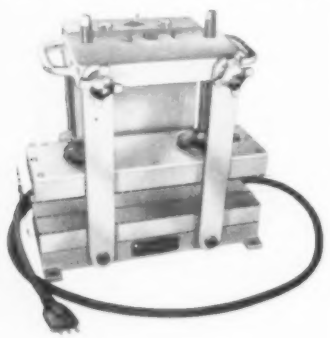
* At the request of a leading advertising agency, a survey was directed to a group of Welding Journal readers specified by the agency. Here is one of the many interesting points that came to light. The actual surveys are available for inspection at any time.

WELDING JOURNAL

For details, circle No. 80 on Reader Information Card

Cable Vulcanizer

The Joy Manufacturing Co., Pittsburgh, 22, Pa., announces a new line of molding presses for reinsulating and rejacketing natural rubber, synthetic rubber and thermoplastic covered cables.



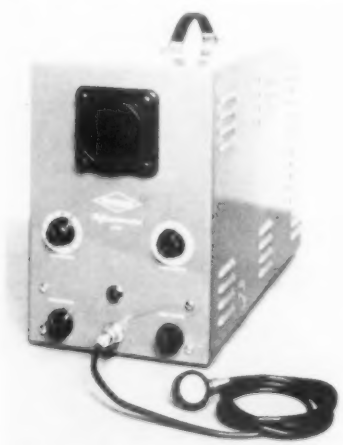
Reputed to accommodate all standard cable types and sizes through the use of interchangeable aluminum molds, these presses carry a 3000-w rating and are currently available for operation on seven standard a-c and d-c voltages.

For more details, circle No. 81 on Reader Information Card.

Portable Reflectoscope

A new portable "reflectoscope" providing high performance, simplified use and versatile application at low cost has been introduced by Sperry Products, Inc., of Danbury, Conn.

The new instrument, identified as Type US, is designed to operate at 2.25 mc and to be used on applications requiring a small portable reflectoscope.



It weighs 35 lb and measures approximately 9 in. wide, 19 in. deep and 14 in. high.

The many possible applications include ultrasonic inspection without disassembly of plant machinery, axles, studs, bolts, welds, forgings, railroad car wheels, dies, pipe, tubing, ingots, billets, blooms, hull plates and refinery equipment.

For more details, circle No. 82 on Reader Information Card.

Air Control Valve

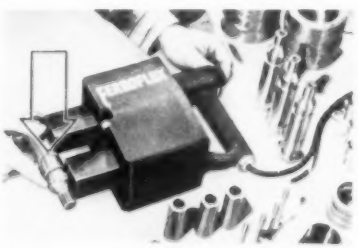
A new pilot-operated air control valve, designed for integral mounting on most makes of portable gun welders, is announced by Valvair Corp., 454 Morgan Ave., Akron 11, Ohio.

Mounted directly on the welding gun cylinder, the new valve is said to provide faster gun response for better welds. Valvair's gun-welder valve facilitates maneuvering the welder in confined areas, it is claimed. Use of a single air supply hose contributes to easier handling and is reported to eliminate excessive air consumption and slow operating cycles associated with remote mounted valves and long connecting hoses.

For more details, circle No. 83 on Reader Information Card.

Magnetic Metal Inspection

Ferro Machine & Tool Co., 5514 W. Washington St., Indianapolis, Ind., announces a portable magnetic-inspection device for the detection of surface and subsurface defects in ferro-magnetic materials.

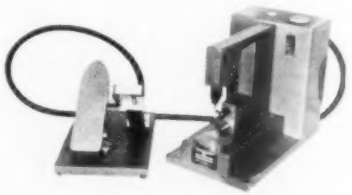


Known as the Ferroflux unit, the device weighs 23 lb and consists essentially of a U-shaped 110-v electro magnet which operates at 0.175 kva. The magnetic field established by the unit is reportedly strong enough to cling to the surface being checked, thus permitting the operator to handle detection fluid without losing control of the operation.

For more details, circle No. 84 on Reader Information Card.

Hydraulic Weld Head

Vacuum Tube Products Co., Inc., 2020 Short St., Oceanside, Calif., announces production of a new heavy-duty hydraulic weld head. The unit, Model VTA-17, is designed for use with VTP resistance-type and capacitance discharge-type welders where measured pressure is desired.

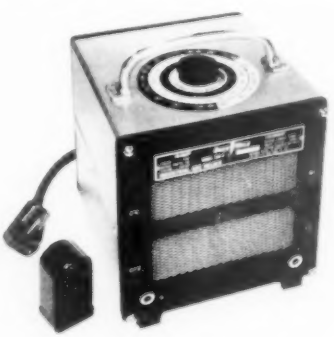


According to the manufacturer, the VTA-17 is a precision low inertia weld head, actuated hydraulically by a foot pedal control. Mounted on the weld head is an automatic weld-pressure firing switch which allows exact adjustment of firing pressure from 0.5 to 100 lb. Integral structural members provide the current conducting path, allowing a heavy current transfer with a minimum of loss.

For more details, circle No. 85 on Reader Information Card.

Portable Arc Welder

Brennan, Bucci & Weber, Inc., 262 Mott St., New York 12, N. Y., announce the availability of their Model 250C Brenn-Weld hand-portable industrial arc welder.



The welder has an output range from 25 to 250 amp with infinite output control and no missing amperes. It handles electrodes from $\frac{1}{16}$ to $\frac{3}{16}$ in. and will weld material from sheet metal up to 2-in. thick steel. Model 250C weighs 112 lb and measures only 12 x 13 x 15$\frac{1}{2}$ in. The open-circuit voltage reportedly enables the use of any a-c welding electrodes. The unit is rated at 50% duty cycle and 200-amp output.

For more details, circle No. 86 on Reader Information Card.

Oxyacetylene Unit

A packaged oxyacetylene-welding outfit, the Redi-Set, has been developed by the K-G Equipment Co. of Allentown, Pa., a subsidiary of Air Products, Inc. According to the manufacturer, Model A.P.M. (all-purpose, medium) will cut up to 4 in. in thickness and will weld materials up to $\frac{1}{2}$ in., while Model A.P.L. (all-purpose, light) will cut to $1\frac{1}{2}$ in. and weld to $\frac{1}{4}$ in.

The unit is sold in either a steel case or a "Kraftboard carton."

For more details, circle No. 87 on Reader Information Card.

Toggle Clamps

The Detroit Stamping Co., 372 Midland Ave., Detroit 3, Mich., has introduced eight new toggle clamps to its line of "Do-Sta-Co" products.

These new clamps are said to maintain a holding pressure of 1650 lb. Made of forged alloy-steel base, they contain re-

placeable components, serrated hardened bushings and staked rivets at all pivot points, a $6^{15}/_{16}$-in. holding bar and $\frac{3}{4}$-in. square cold-drawn bars and handles. There are two basic models: Series 527 when overhead work clearance is a factor and Series 528 for other applications.

For more details, circle No. 88 on Reader Information Card.

Model 52 Multitron

"We Save More Than 50% of Radiography Costs on Welding Inspection by Using Nuclear Systems' Equipment"

This statement was made recently by Mr. J. C. Abbott, General Superintendent of Manufacturing at the Chattanooga, Tennessee plant of Combustion Engineering Inc., manufacturers of steam generating and related equipment, nuclear power systems and other products.

"In inspecting welding, we're using two Nuclear Systems gamma radiography machines 18 hours a day," continued Mr. Abbott. "Soon we'll have them in operation 24 hours a day at which time we expect to save up to 75% on radiography costs when compared with X-ray.

"In using X-ray we required expensive rigging to bring the work to the machine; now we simply move the easily portable Nuclear Systems machines around to our work locations."

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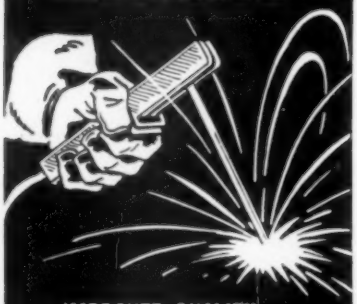

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For details, circle No. 95 on Reader Information Card

Ultrasonic Welder

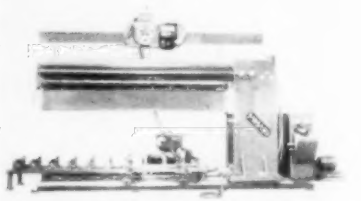
Gulton Industries, Inc., Metuchen, N. J., have developed their Ultrasonic Aluminum Foil Welder for continuous seam welding of aluminum foil. With potential applications in the packaging and electrical industries, the unit can

reportedly be installed in automatic production-line systems or used in manual operation. According to Gulton, the unit is powered by a 100-w ultrasonic generator and operates at 20,000 cycles. The welder has joined aluminum thicknesses of 0.0003 in. in tests.

For more details, circle No. 90 on Reader Information Card.

Welding Positioner

Development of a new, high-pressure longitudinal welding positioner for joining metals up to $\frac{1}{2}$ in. thick in any regular shape form sheet to cones or cylinders up to 54 in OD, has been announced by Airline Welding and Engineering, 785 N. Prairie Ave., Hawthorne, Calif.



A feature of the equipment, designated Model LW10920, is a special Hydro-Booster unit that activates two parallel continuous banks gripping "fingers."

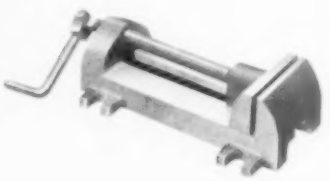
Several interchangeable mandrels are available. They are equipped with thermostatically controlled oil-heating devices designed to preheat the weld joint and postheat the weld in crack-sensitive metals. The mandrels can be heated up to 600° F.

Model LW10920 includes tungsten-arc inert-gas-shielded apparatus controlled electronically along the full length of the mandrel. Other welding processes may also be used.

For more details, circle No. 91 on Reader Information Card.

Drill Press

A new heavy-duty drill-press vise, manufactured by Alva Allen Industries, Clinton, Mo., Model X4V is reportedly designed for all types of drill-press work and other similar operations. The main body and jaw are machined from grey iron with a threaded steel screw.



Jaws have 4 in. width, 2 in. depth and 7 in. opening. Base size over-all is $6\frac{3}{4}$ x $11\frac{1}{4}$ in. Net weight is $18\frac{1}{2}$ lb.

For more details, circle No. 92 on Reader Information Card.

Reverse-Current Cleaner

Oakite Composition No. 190, a new reverse-current cleaner, has just been made available by Oakite Products, Inc., 19 Rector St., New York 6, N. Y.

Oakite Composition No. 190 is effective in cleaning heavily smutted steel. It is also said to remove fingerprints, light surface rust and oxides resulting from spot or seam welding.

For more details, circle No. 93 on Reader Information Card.

Torch to Weld Zircaloy

Vacuum Specialties Co., Inc., Somerville, Mass., have developed an automatic welding torch to supply filler metal in Zircaloy welds, as found in the nuclear fuel element industry. The torch is also recommended for such metals and alloys as zirconium, titanium and molybdenum.

The torch itself is a unit within the welding chamber. Feed wire sizes range from 0.020 to 0.125 in. diam with a maximum current of 1200 amp. The complete assembly can be used as a consumable torch or as a cold wire feeder to the company's Vasco thoriated-tungsten automatic torch, Model T-2.

For more details, circle No. 94 on Reader Information Card.

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SUPPLEMENT TO THE WELDING JOURNAL, AUGUST, 1958

DIFFUSION BONDING BELOW 1000° F

Paper describes the techniques and metal systems used to obtain joints between beryllium copper and Monel

BY J. T. NIEMANN, R. P. SOPHER AND P. J. RIEPPEL

It is sometimes necessary to join metals which cannot be welded or brazed because of metallurgical incompatibility, and some metals may require a post-joining heat treatment that rules out brazing and welding. In such cases, diffusion bonding can often be used. Diffusion bonding may be defined as a joining method in which the metals to be joined are heated to a temperature below their solidus temperature and held under pressure for some length of time. No liquid phase is formed and bonding occurs by movement of atoms across the interface at asperities on the surfaces where intimate contact occurs. The contact area of the asperities is increased as the metals flow under load. The remaining areas which are not in contact may be partially, or completely, filled by the diffusion process.

The fabrication of throat blocks for hypersonic wind tunnels is an application in which diffusion bonding was considered. Figure 1 shows a sketch of the arrangement of the blocks forming the throat section of a wind tunnel. The operating conditions of the wind tunnel require that the throat blocks be water cooled. Figure 2 is a photograph of a throat block and cover sheet. The cover sheet must be joined to the block along all the edges and also on the interior ribs to seal the cooling water

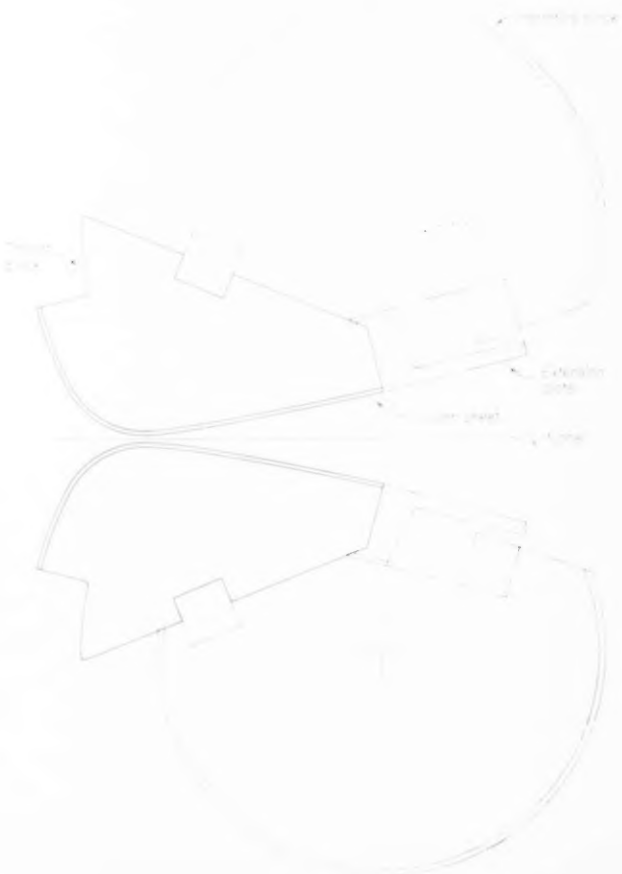


Fig. 1 Sketch showing arrangement of throat blocks in wind tunnel

J. T. Niemann is Welding Engineer, R. P. Sopher, Assistant Chief, and P. J. Rieppel, Chief, of the Metals Joining Research Division of Battelle Memorial Institute.

Paper presented at AWS 1958 Annual Spring Meeting held in St. Louis, Mo. April 14-18.

passages and to provide sufficient strength to resist internal pressure.

The cover sheet material must have high strength, good thermal conductivity and formability. The backing-block material must have about the same coefficient of expansion as the cover sheet and, in addition, be corrosion resistant and machinable.

One proposed throat-block design for the Flow Converter B hypersonic wind tunnel located at the Arnold Engineering Development Center consisted of a copper-2% beryllium alloy cover plate joined to a contoured Monel backing block. It was anticipated that edge welding of the cover sheet to the backing block might be necessary. Therefore, Monel, rather than stainless steel, was selected for this application. Beryllium copper was not used for the block because it undergoes dimensional changes during final age-hardening treatment. The Monel blocks were to be about 40 in. long by 20 in. wide by 8 in. thick over all. The cooling water channels were to be approximately 0.5 in. wide and separated by 0.10-in. wide ribs. It was planned that the blocks would operate at an internal water pressure of 800 psi, but be proof tested at 1500 psi.

The operating conditions of the flow converter necessitate heat treating the beryllium-copper cover plate to a minimum tensile strength of 180,000 psi. The heat treatment of beryllium copper consists of two operations, solution annealing and age hardening. Solution annealing is accomplished by heating the material to 1400° F, holding for 1 hr per in. of section and then water quenching. The material is then age hardened by heating to 650° F and holding for 3 hr.

It would be possible to braze these assemblies using an alloy which has a melting point above the solution-annealing temperature (1400° F) and below the solidus temperature of beryllium copper (about 1600° F). However, it would be necessary to quench the assemblies from 1400° F. Experience showed that the quenching might result in failure of the brazed joints and would certainly cause undesirable distortion in the Monel blocks. The final machining operation consists of grinding the cover sheet. Any distortion which occurred during heat treating would result in nonuniform cover-sheet thickness.

In view of the problems involved in quenching brazed assemblies, diffusion bonding was investigated as a possible method of fabrication. This method would entail the diffusion bonding at 650° F of a beryllium-copper sheet previously solution annealed at 1400° F to the Monel backing block. During the 3-hr holding period at 650° F (the diffusion bonding period), the beryllium-copper sheet ages to the desired high-tensile strength.

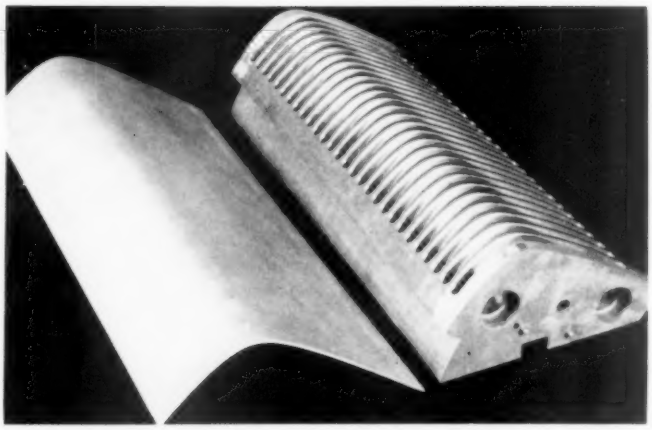


Fig. 2 Photograph of throat block and cover sheet

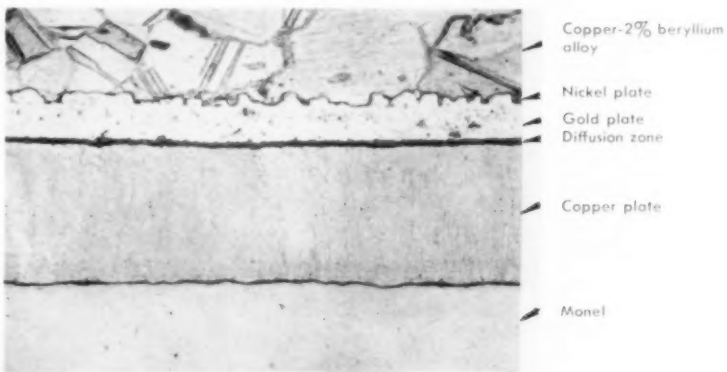
This paper describes the techniques and metal systems used to obtain joints between the beryllium copper and Monel. The program was concerned with investigating joining techniques which could be used ultimately in the fabrication of throat blocks.

Preliminary Bonding Studies

Although diffusion bonding appeared to be a good method of fabricating the throat-block assemblies, past experience in diffusion bonding beryllium copper to Monel showed it was difficult to obtain consistently good joints at 1400° F.[1] One of the problems in joining the alloys was the oxide film which forms on beryllium copper. Therefore, it was decided that both the beryllium copper and Monel should be electroplated with other metals more likely to diffuse at 650° F.

Some of the factors which may influence diffusion of metals are atomic size, valence, melting points and solubility limits. However, which of these factors is predominant in determining diffusion behavior may vary with the metal system being investigated. In addition, the effect of solubility limit may be a function of temperature.[2] On the basis of existing knowledge, only generalities can be made about diffusion phenomena. A fundamental investigation of diffusion was not within the scope of this program. Consequently, the metals evaluated were selected on the basis of their tendency to form solid solutions or intermetallic compounds. The metal systems studied are listed in Table 1.

One-inch square pieces of Monel and/or beryllium copper were surface ground and then electroplated with the metals being investigated. In some cases, electroplated surfaces were used in conjunction with metal foil. After the plated surfaces were cleaned with 600-grit emery paper and washed with acetone, they were placed in a die set. This assembly was heated to 650° F in an atmosphere furnace which was designed so that a load could be applied to the die set. A load of 6200 lb per sq in. of



Etchant: 60 parts tincture of iodine plus 40 parts 5% KI solution

Fig. 3 Photomicrograph of gold-plated beryllium copper diffusion bonded to copper-plated Monel at 650° F. X 500 (Reduced by 25% upon reproduction)

Table I—Metal Systems Studied

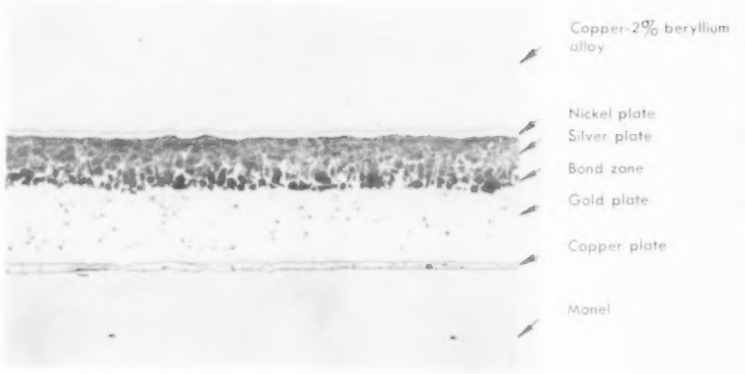
Metal combination	*Atomic radius, A°*	*Type of alloy system*
Ag Cu	1.44 1.28	Partial solid solubility
Au Ag	1.44 1.44	Complete solid solubility
Au Pb	1.44 1.75	No appreciable solid solubility, form intermetallic compounds
Au Cu	1.44 1.28	Complete solid solubility, ordering reaction
Ni Cu	1.25 1.28	Complete solid solubility
Al Au	1.43 1.44	Partial solid solubility, intermetallic compounds
Au Ni	1.44 1.25	Complete solid solubility, ordering reaction
Fe Ni	1.28 1.25	Complete solid solubility, allotropic transformation

joint area was applied to the specimen prior to heating. Bonding was done in either a helium or nitrogen atmosphere. The specimens were held at temperature for 3 hr, furnace cooled, and then prepared for metallographic examination.

The systems which showed good bonding were gold-copper, gold-silver, gold-lead and gold-aluminum. There was no appreciable amount of diffusion in any of the other systems tested. However, diffusion no doubt would occur in all the systems at higher temperatures. Photomicrographs of the gold-copper, gold-silver, gold-aluminum and gold-lead systems are shown in Figs. 3 through 6, respectively. In some cases, the metals being studied were not plated directly on the beryllium copper or Monel; an intermediate layer was used to insure good adherence.

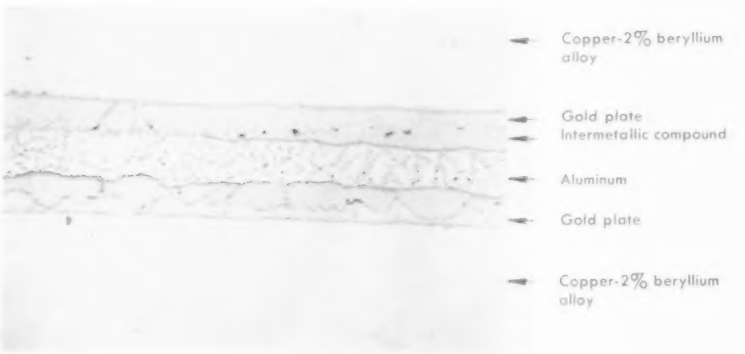
Both the gold-aluminum and gold-lead systems contain intermetallic compounds. In the gold-aluminum joint shown in Fig. 5, a 2-mil thick piece of aluminum was placed between two gold-plated pieces of beryllium copper. In the gold-lead specimens, the gold-plated beryllium copper was plated with 0.010 mil of lead and used with gold-plated Monel. In this case, the bonding temperature was above the melting point of lead (621° F). Apparently, the lead melted and filled areas of the joint where there was not complete contact between the two pieces. This movement of the lead left areas of gold in direct contact, and these areas bonded by self diffusion. In addition, the molten lead alloyed with the gold forming a compound.

The next step in the investigation was concerned with determining the effects of time and temperature on the depth of the diffusion zone when the



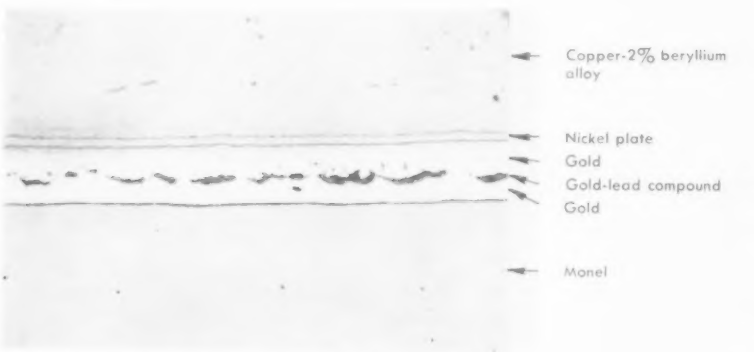
Etchant: 20% chromic acid

Fig. 4 Photomicrograph of silver-plated beryllium copper diffusion bonded to gold-plated Monel at 650° F. X 500. (Reduced by 25% upon reproduction)



As polished

Fig. 5 Photomicrograph of gold-plated beryllium copper diffusion bonded to gold-plated beryllium copper with aluminum at 650° F. X 500. (Reduced by 25% upon reproduction)



Etchant: 1 part tincture of iodine plus 1 part 20% chromic acid

Fig. 6 Photomicrograph of gold-lead-plated beryllium copper bonded to gold-plated Monel. X 500. (Reduced by 25% upon reproduction)

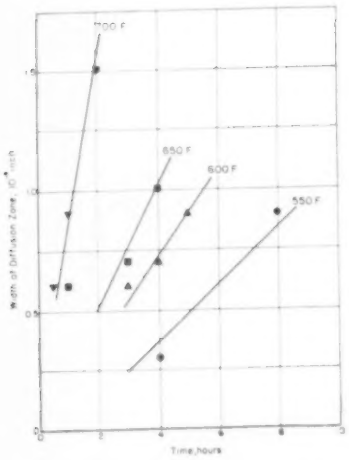


Fig. 7 Graph showing effects of time and temperature on width of diffusion zone of copper and gold joints

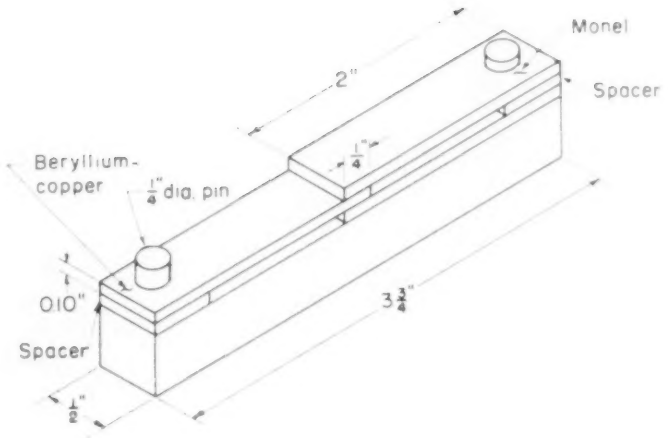


Fig. 8 Sketch showing double-lap shear specimen and aligning jig

gold-copper system was used. This was done to determine if the age-hardening treatment for the beryllium-copper alloy could be changed to provide conditions that would produce a better joint. The results of these studies are shown graphically in Fig. 7. Hardness readings were made to estimate the strength level of the beryllium copper. These readings indicated that all but the 550° F treatment produced the desired strength of 180,000 psi. The specimens aged at 550° F probably had tensile strengths of at least 160,000 psi.

These samples were brought to temperature with the furnace and also furnace cooled. The heating and cooling cycles varied for each specimen, so the data shown in Fig. 7 should be viewed as showing a trend rather than representing absolute values. These results show that temperature has a greater influence on depth of diffusion than does time. For instance, the same depth of diffusion can be obtained at 700° F in 1 hr, 600° F in 5 hr, or 550° F in 8 hr. The same type of time-temperature relationship exists in the aging cycle of copper-2% beryllium alloy. If this alloy is aged at 650° F, the time required to obtain optimum properties is 3 hr; whereas at 700° F less than 1 hr is required.[5,6] As a result, there was apparently no advantage in changing the age-hardening treatment, so all additional bonding was done at the recommended temperature of 650° F for 3 hr.

Evaluation of Joint Strength

The preliminary bonding studies showed that diffusion bonding could be accomplished during the age-hardening treatment of beryllium copper. The next step in the investigation was to determine which of the four alloy systems that showed promise in the preliminary studies was the most satisfactory from the standpoint of strength. The ultimate method of determining the suitability of the diffusion-bonded joints would be fabricating and evaluating simulated throat blocks. However, these simulated blocks are expensive to prepare, so it was decided to select the best systems by determining the strengths of joints prepared with each of

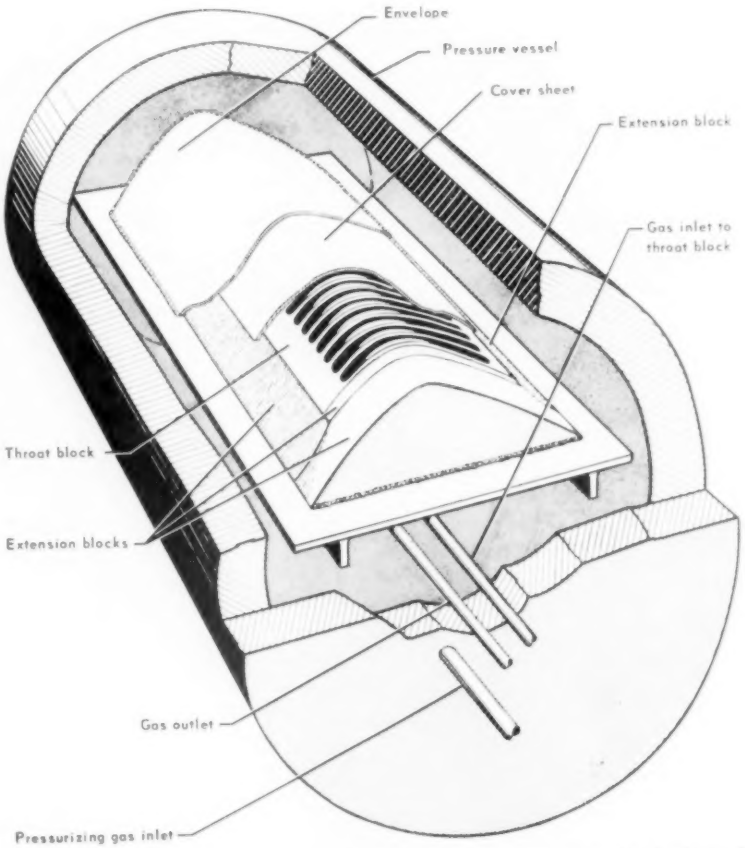


Fig. 9 Sketch of throat-block assembly setup for bonding under hydrostatic loading

the four systems. The system having the best strength would then be evaluated further by simulated throat-block specimens.

Determination of Joint Strength

Diffusion-bonded joints tested in tension would provide strength values directly applicable to the throat-block application. Tension-test specimens, consisting of two $\frac{1}{4}$-in. diam by 1$\frac{1}{2}$-in. long stainless-steel rods, were prepared. The metals to be studied were plated on the ends of the rods. The rods were enclosed in a sleeve, placed in a furnace, and then heated under load. However, it was difficult to maintain uniform loading which is necessary for complete bonding. Therefore, the results of these tests were inconclusive.

The tension tests did indicate that diffusion-bonded joints possess tensile strengths in excess of 20,000 psi. However, it was decided that further effort should be made to evaluate joint strengths. In order to overcome the loading problems, double-lap shear specimens were prepared in a die set. The shear-strength values cannot be applied directly to the throat-block application as well as tensile-strength values, but the information obtained would serve in selecting the best combination of materials for diffusion bonding.

The type of shear-test specimen and aligning jig used are shown in Fig. 8. The specimen and aligning jig were placed in a flat die set for loading. A load of 7200 psi of joint area was applied to the specimen during bonding.

The gold-copper, gold-silver, gold-aluminum and gold-lead systems were evaluated by shear-strength tests. Three specimens of each type were prepared. The gold-lead and gold-aluminum samples were so brittle that they failed during removal from the aligning jig or while being placed in the testing machine.

The gold-copper system had a maximum shear-strength value of 13,400 psi, a minimum value of 7800 psi and an average shear strength of 10,150 psi. The gold-silver system had a maximum shear-strength value of 13,200 psi, a minimum value of 8750 psi and an average shear strength of 10,550 psi. The maximum values were considered the most important in that they showed the strength of apparently completely bonded samples, whereas the average and minimum values were nominal since considerably less than 100% of the area was bonded.

On the basis of these results, both the gold-copper and gold-silver systems seem to have sufficient strength for the throat-block application. It may be assumed that the tensile strength of these joints would be at least 20,000 psi, which should be sufficient. The tensile strengths of gold and silver are about 20,000 psi. Copper has a tensile strength of about 32,000 psi. The joints made with these metals could be as strong or stronger than the metals themselves because of the alloying that takes place and the state of stress that exists because of the joint dimensions.

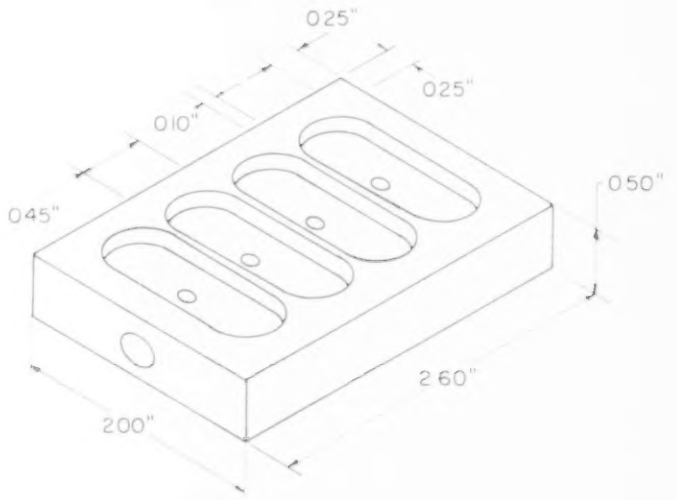


Fig. 10 Sketch of flat simulated throat block

One of the problems involved in the fabrication of throat blocks is forming the cover sheet to the contour of the block and maintaining intimate contact during bonding. It was believed that hydrostatic loading of the cover sheet would be the most satisfactory method of obtaining intimate contact between the cover sheet and backing block. A proposed method of hydrostatic loading is shown in Fig. 9. This method consists of completely enclosing the cover sheet and block in a stainless-steel envelope by welding. The envelope assembly is placed in a pressure vessel which is heated in a furnace. Gas pressure is introduced into the vessel, forcing the cover sheet to conform to the shape of the throat block.

Before hydrostatic loading could be used in conjunction with diffusion bonding, it was necessary to determine the optimum sheet thickness and gas pressure. The sheet must be thick enough to resist being deformed into the channels and yet thin enough to be formed to the contour of the throat block. After the final machining operation on the B throat blocks is completed, the cover plate thickness will be about 0.050 in. thick. The initial sheet thickness will be 0.060 in. or greater.

Specimens used to determine the minimum sheet thickness consisted of stainless-steel blocks in which four channels, 0.450 in. wide by 3 in. long, separated by 0.10-in. wide ribs were machined. These channels were covered with a beryllium-copper sheet and the assembly sealed by edge welding a stainless-steel diaphragm (18 gage) to the blocks. The specimens were then subjected to a gas pressure of 2000 psi and heated to 650° F. Two sheet thicknesses were investigated, $\frac{1}{16}$ in. and $\frac{1}{8}$ in. It was found that the $\frac{1}{16}$-in. thick sheet had deformed into the channels, but the $\frac{1}{8}$-in. thick sheet had not. These results indicated that, if $\frac{1}{16}$-in. thick sheet is used, the pressure must be lowered.

Next, two flat simulated throat blocks were bonded under hydrostatic pressure. A sketch of the blocks is shown in Fig. 10. The channel and rib widths approximate those of the Flow Converter B throat blocks. Stainless steel was used in place of Monel because it was more readily available. This substitution of the block material should not affect the joint strength appreciably because bonding occurs between plated metals.

The blocks were plated with 1 mil of copper and the $\frac{1}{16}$-in. thick beryllium-copper cover plates with 1 mil of gold. The cover plate and block were placed in a stainless-steel box and sealed by edge welding a stainless-steel diaphragm to the box. The final welding operation was done in a helium-filled welding chamber, thereby sealing an inert atmosphere in the throat-block channels. Both specimens were bonded at 650° F for 3 hr, the first under a pressure of 1500 psi, and the second under a pressure of 1000 psi. The bonded assemblies were pressure tested, and the first failed at an internal pressure of 5200 psi, and the second at 3000 psi. In both cases, the beryllium-copper sheet had been depressed into the channels,

These results indicated the need for maintaining a hydrostatic pressure of at least 1500 psi. However, this pressure resulted in excessive deformation (>0.010 in.) of the $\frac{1}{16}$-in. thick beryllium-copper sheet into the channels.

The tests described above were repeated using 0.090-in. thick beryllium copper. Two assemblies were bonded under a hydrostatic load of 1500 psi. The depression of the sheet into the channels was measured after bonding and found to be 0.003 in. The maximum allowable deformation is 0.005 in. These blocks were pressure tested and failed at internal pressures of 4800 and 6500 psi. The block which withstood the higher pressure was bonded more thoroughly around the edges.

Conclusions

The results of the investigation show that certain metals can be joined by diffusion bonding at 650° F or perhaps lower. Good joints were obtained with the following metal combinations: gold-copper, gold-silver, gold-lead and gold-aluminum. From the standpoint of strength, gold-copper and gold-silver were comparable (13,000 psi shear) and superior to the gold-lead and gold-aluminum combinations which were found to be quite brittle.

The results of this investigation indicate that hypersonic wind-tunnel throat blocks of the type described in this paper could be fabricated by diffusion bonding if the backing block and cover sheet are first electroplated with suitable metals. The diffusion-bonding technique permits the joining of the beryllium-copper cover sheet and the Monel block at the age-hardening temperature of the beryllium copper. This procedure eliminates the need for quenching the entire assembly from the 1400° F solution-annealing temperature. A quench from this temperature would distort the throat-block assemblies to the extent that they could not be machined to meet the thickness tolerances of the beryllium-copper cover sheet.

Although this study was concerned primarily with beryllium copper and Monel, there is no reason to believe that other metals could not be joined by the same technique.

Acknowledgment

The authors wish to express their appreciation to the Arnold Engineering Development Center, Tullahoma, Tenn., for permission to publish this information.

The authors also wish to acknowledge the assistance and technical counsel offered by D. C. Martin and C. B. Voldrich, of Battelle Memorial Institute. Special acknowledgment is due to Lt. Col. L. K. Carson and Major G. S. Brownell, of the Arnold Engineering Development Center, and Mr. E. J. Stollenwerk, of Aro, Inc., for their cooperation during this investigation.

Bibliography

1. Niemann, J. T., Sopher, R. P., and Riepped, P. J. "Brazing Flow Converter E-2 Throat Blocks." Summary Report to Air Research and Development Command from Battelle Memorial Institute. Contract AF 18(600)-381 (June 28, 1957).

2. Sawatzky, A., and Jaumot, F. E., Jr. "Diffusion of the Elements IB and IIB Subgroups in Silver." *Journal of Metals*, 9 (10): 1207-1210 (1957).

3. Smithells, C. J. *Metals Reference Book*. Second Edition, Vol. 3. Interscience Publishers, Inc., New York: 179-180 (1955).

4. Richards, J. T. "Beryllium—Copper." *Materials and Methods*, 76-90 (April 1950).

5. Richards, J. T. "How to Get More Out of Beryllium Copper." *Materials and Methods*, 112-114 (December 1956).

RESEARCH NEWS

Observation Concerning Metal Fatigue

An interesting surface phenomenon occurring during metal fatigue has recently been observed at the National Bureau of Standards mechanical metallurgy laboratory. The observation provides a technique that promises to be of value in studying the effect of surface reactions on metal fatigue. Also, it may have practical application in the early detection of fatigue cracks.

Metals subjected to repeated or fluctuating loads sometimes break after many cycles of stress. This type of failure, referred to as fatigue, begins as a tiny crack that gradually progresses through the metal undergoing stress. Previously, time-lapse motion pictures of a fatigue fracture in an aluminum alloy had shown materials being extruded from the cracks in surprisingly large amounts, considering the size of the cracks.[1]

In an attempt to obtain some of this material for identification, Irene C. Minor applied a piece of transparent pressure-sensitive tape to the surface of a torsion fatigue specimen. Fatigue cracks had already been induced in the metal by several thousand cycles of reversed stress. When the specimen was then stressed for an additional thousand cycles, small bubbles formed under the tape.

Fig. 1 Comparatively large and numerous bubbles have formed under the transparent tape applied to the stressed specimen of an aluminum alloy. The metal had been stressed for 100,000 cycles before the tape was applied, and several fatigue cracks had developed. An additional 2000 cycles of stress produced the bubbles shown here

A series of investigations disclosed that bubbles formed as soon as detectable cracks were present. Even when the cracks were so small they could be seen only with a microscope under special lighting, the bubbles were large enough to be readily seen with the unaided eye. For this reason, it appears that this observational technique may be used to detect the onset of fatigue cracking.[2]

Apparently, the bubbles can be produced with some metals and not with others. In the experiments thus far, the tendency of various stressed metals to form bubbles was observed as follows:

5052-H34 aluminum alloy	strong
2024-T3 aluminum alloy	strong
Mild steel (cold rolled)	moderate
Stainless steel	very weak
Brass	none
Zinc	none

These differences suggest that the phenomenon is due to surface reactions; however, further studies must be made before the mechanism of the effect can be fully explained.

[1] See Motion pictures of metal fatigue. NBS Tech. News Bull., 40, 153 (1956).

[2] A patent for this process has been applied for (NBS serial 682,071).

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Operation Deepfreeze

Some of the mysteries of ironmaking may be solved by scientists of United States Steel Corp., who conducted an

(*Continued on page 374-s*)

CONTROL OF MELTING RATE AND METAL TRANSFER IN GAS-SHIELDED METAL-ARC WELDING

PART I—CONTROL OF ELECTRODE MELTING RATE

Heat for electrode melting found to be produced simultaneously by the anode or cathode reactions, depending on the polarity, and resistance of the welding wire to the flow of current

BY A. LESNEWICH

ABSTRACT. Gas-shielded metal-arc welding can be used to tailor the weld penetration, the deposition rate and general character of the weld metal to the needs of specific applications. Great versatility can be achieved by adjusting process variables to regulate the electrode melting rate and the mode of metal transfer. However, if the effects of these adjustments are not understood thoroughly, operating difficulties may be encountered, since substantially the same variables control both the melting rate and metal transfer, and a change in the electrode melting rate may be accompanied by a simultaneous, unwanted change in the characteristics of transfer.

For clarity, the discussions of melting rate and metal transfer have been separated in this report. The former is considered in Part I; the latter, in Part II.*

The heat for electrode melting is produced simultaneously by the anode or cathode reactions, depending on the polarity, and resistance of the welding wire to the flow of current. Only a small portion of the heat is received by radiation from the arc stream or the weld crater. Anode heating is affected by the electrode diameter and the magnitude of welding current. Cathode heating also is dependent upon these factors and, in addition, upon the electrode extension and activation. Electrical-resistance heating is controlled by the electrode extension, diameter and resistivity, and the current magnitude. The arc length has a measurable effect on melting rate only in a very few welding applications.

Introduction

Inert-gas metal-arc welding has received general acceptance for joining aluminum, titanium, super-alloys, certain grades of stainless steel and other costly metals because this process permits them to be joined without difficulty at low cost by welds of excellent quality. Carbon steels, on the other hand, can be joined easily with a variety of reliable fusion-welding processes that are frequently more economical and sometimes more versatile than the inert-gas metal-arc method. Nevertheless, gas-shielded metal-arc welding often becomes the favored method of joining carbon steels when the elimination of flux, attainment of high welding speed, precise positioning of weld metal, complete control of welding variables or use of very high duty cycles is required.

The introduction of low-cost carbon dioxide as a protective gas in welding mild steels has caused a tremendous increase in the use of gas-shielded metal-arc welding in applications heretofore limited to other processes. Carbon-dioxide shielding is more economical than argon shielding because more metal can be deposited per given unit-cost of gas and, therefore, it is used in spite of the fact that much more control of the welding variables is needed to keep spatter, porosity and oxidation of alloying elements at a minimum.

Any method that increases the weld deposition rate without requiring an increase in the flow of inert gas would have the same relative effect upon the cost of weld metal as reducing the cost of shielding gas. This method would result in a reduction in cost without sacrificing spatter-free transfer and ease of arc control, and would be applicable to all metals, even those that cannot be shielded with carbon dioxide.

This research was undertaken to determine how much control of melting rate could be obtained by varying the mechanics of gas-shielded metal-arc welding. The outcome of this work indicates that many variables must be controlled if consistent results are to be achieved, and that the welding engineer has much more control of the weld deposit than he sometimes realizes. They also have provided a better understanding of the factors that regulate melting of the electrode and an explanation of phenomena such as the self-regulation of the arc length in gas-shielded metal-arc welding.

The fact that both electrical-resistance heating in the wire and arc heating supply energy to melt welding electrodes has been appreciated for some time.[1,2] Most of the published information concerning the relative importance of the two heat sources has been based upon data obtained with submerged-arc welding. However, these results are not always applicable to gas-shielded arc welding, and because the arcs are hidden, a complete understanding of the effect of welding variables on the heat developed and the melting rate of the electrodes has not been possible. As a result, a number of misconceptions regarding the origin of melting energy has arisen; some of these are regarded almost as self-evident truths.

The purpose of this part of this report is to discuss the variables that affect electrode melting rates and to explain the development of a general equation that can be used to aid the selection of welding conditions for particular welding applications.

Possible Sources of Melting Energy

Gas-shielded metal-arc welding is basically the same as older arc-welding processes in the sense that electrical power is used to melt the electrode and

A. Lesnewich is associated with the Research Laboratories of Air Reduction Co., Inc.

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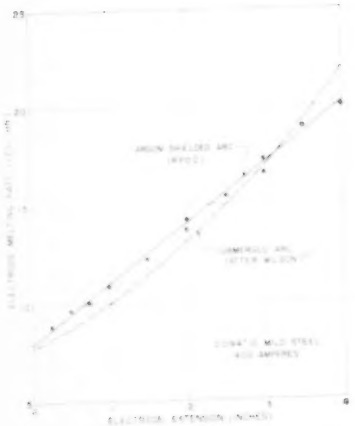

Fig. 1 Effect of electrode extension on its melting rate. Comparison of inert-gas metal-arc and submerged-arc processes

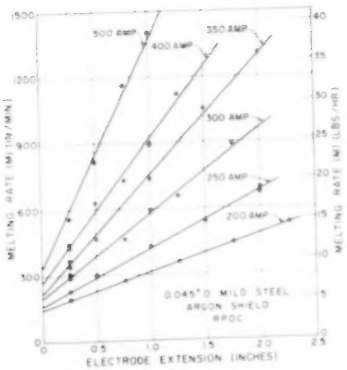

Fig. 2 Effect of electrode extension and welding current on the electrode melting rate

weldment. Since the magnitude of welding current is the same throughout the welding circuit, voltage drops in various regions of the circuit are a measure of the power absorbed or dissipated within them; these voltages add up to the voltage needed at the terminals of the power supply.

In considering the circuit external to the power supply, the following can be noted. A moderate loss of power is caused by resistance heating of welding cables, jigs, fixtures and other essentials of the welding circuit. Negligible losses due to resistance heating are produced in the conducting elements of the welding gun and across the interface between the contact tube in the gun and the electrode. The remainder of the power is expended in the arc and the electrode, and accounts for most of the voltage at the terminals of the power supply.

This major expenditure of energy causes current to flow through the small-diameter electrode, releases electrons from the cathode and forces them into the anode, and maintains complex reactions within the arc stream to keep it conducting. All of these reactions generate heat that is either used ultimately for melting, or is lost to the atmosphere or equipment by radiation or conduction. Unfortunately, absolute values of the various voltages cannot be measured directly. They cannot be calculated since almost all postulated reactions within the arc are based on low-current arcs between nonconsumable electrodes. It would be too much to expect that these postulates would be entirely adequate for high current-density arcs; particularly those with the complicating factor of metal in transfer. These hypotheses do, however, offer some idea of the mechanisms that control the arc, and very brief descriptions of them will be given to explain the origin of heat for melting.

Until recently, gas-shielded consumable-electrode welding was done only with reverse-polarity direct current. For this operating condition, the electrode is melted by the heat developed by its own resistance to the flow of current, by anode reactions, and by radiation from the arc stream and the weld pool. Straight-polarity direct-current arcs utilize cathode rather than anode heating for electrode melting without changing the other factors. Consequently, the melting rate with straight polarity will differ from that of reverse polarity by roughly the difference in the anode and cathode heating. Alternating-current arcs supply heat to the electrodes by all of these reactions. Consequently, their rate of melting is between those developed with reverse and straight-polarity direct current.

Experimental Method

The various sources of energy for melting were isolated and measured quantitatively by changing one welding variable at a time and observing the change in melting rate that was produced.

Electrode extension or stick-out (the distance between contact tube and the arc) was the easiest variable to study. The effect on electrode melting rate of changing the extension was determined while holding the arc length, current and other variables fixed. Typical results of such measurements are shown with the solid curve of Fig. 1; the melting rate increases linearly with increasing stick-out.

Electrode extension is the distance from the point at which it picks up current and its tip in contact with the arc. The extension is not necessarily the distance between the contact tube and the work surface since this does not take into account the presence of an arc. It is not valid to compensate for the arc by using the welding voltage as a measure of arc length since both the arc voltage and the voltage drop in the electrode are strongly affected by the welding current; at the same time, the changes in arc voltage due to differences in penetration and the plasma or electrode drops cannot be determined or controlled with ease. If these methods are used to measure stick-out (i.e., a constant distance between the contact tube and the work surface, and a fixed welding voltage) the arc length and actual electrode extension will vary with current and yield a non-linear relationship similar to that shown by the dashed curve in Fig. 1. Only with the open arcs of the gas-shielded process can the arc length be measured; the assumptions and research techniques that are necessary with flux-shielded methods lead to the dashed, exponential curve of Fig. 1.

Extrapolation to zero stick-out of curves similar to those in Fig. 1 provides the melting contribution at a particular level of current of all sources of heat other than that developed by electrical-resistance heating of the electrode; they include anode or cathode, and radiation heating.

The effect of welding current upon melting rate was found by holding arc length and stick-out fixed, and varying the magnitude of current. A typical plot of such data is illustrated in Fig. 2, and shows that the melting rate is dependent upon both current and stick-out, and, since none of the curves are parallel, that the two are inter-related in some manner. A mathematical expression for this relationship was easily found.

By repeating essentially this same procedure, changing only one welding variable at a time and plotting these data against one another, the contributions of the various sources of energy were isolated and their effect upon the total heat for melting was expressed with empirical equations.

Values of current, wire speed and voltage were obtained with recording meters. The wire-speed transducer was a small d-c generator. The generator voltage was reduced with a voltage divider and fed to a recording potentiometer. This method of recording the wire speed is sufficiently sensitive to indicate any changes caused by uneven wear of the drive rolls. The current and voltage readings were accurate to 2% of the absolute value. Violent fluctuations in the signals caused by globular metal transfer sometimes made these readings difficult; their median values were recorded.

Arc length was measured by projecting a magnified arc image upon a calibrated screen. Although readings within 0.01 in. were possible, this accuracy is optimistic since some judgment on the part of the technician was needed to

locate precisely the position of the electrode tip. Differences in the tip shape made this problem doubly difficult. A flat, or at least blunt, tip would have been easy to measure, but the tip usually encountered is needle-like or made of large, oscillating drops.

Arc-length and stick-out measurements were standardized as shown in Fig. 3. With spray transfer, the effective electrode terminal of the arc was selected as a point one-third the distance from the base of the inverted cone forming the tip to the actual end of the electrode. With drop transfer, the average position of the base of the drop was considered as the arc terminal. Even these conventions were impractical at times. Some arcs are unusual in that the plasma may envelop the electrode as far as $\frac{1}{8}$ in. from its tip. If the effective electrode tip is assumed to be $\frac{1}{8}$ in. the distance from the tip to the point at which the arc envelopes the electrode, the tip would be in touch with the work surface when the effective arc length is considered to be $\frac{1}{4}$ in. However, such arcs are not generally used commercially, and can occur only with incompletely activated electrodes and straight-polarity direct current. Consequently, when these arcs were encountered, they were considered to originate at the apparent tip of the electrode. This would result in a melting rate lower than that to be found by using the established convention.

Only the apparent arc length was measured since the true arc terminal at the plate is at some point within the crater. Subsequent work showed that variations in arc length had only minor effects on melting rate, so it was not necessary in this study to determine subsequently the effect of true arc lengths.

Some question might be raised regarding the point of current pickup within the contact tube, and, therefore, about the measurement of electrode extension. This could be a problem with a straight welding wire because point contact might be made at changing positions within the tube. However, care was used to select wire having sufficient cast to be forced into contact at the edge of the tube but not so great a cast that arc wandering or inaccuracies in extension determinations would result.

Metals and Gases Studied

Most of the reported data were obtained with a commercial mild-steel welding wire. However, the same basic principles would define the melting rates of all materials although the order of magnitude of the different factors would change. The electrodes under discussion were of the same analysis unless specified otherwise. In a like manner, argon shielding gas was used for most of the work although other inert and active gases also were used; any change from argon will be indicated.

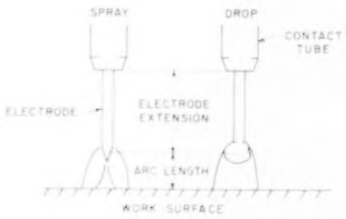

Fig. 3 Conventions used to determine electrode extension and arc length

Limitation of Study

Gas-shielded arcs only were investigated, but it is thought that the same basic concepts will apply to submerged-arc and covered-electrode processes as well. Wire sizes were limited to those diameters used commercially for gas-shielded arc welding; they varied from 0.030 to 0.094 in. Stick-out limits were imposed by burn-back difficulties with short arc lengths, and arc wandering, starting difficulties and arc instability that develop with long extensions. These limits were somewhat dependent upon the wire diameters, but, in general, the minimum was $\frac{1}{4}$ in. and the maximum was 2 to 3 in. Adequate shielding with long wire extensions was achieved by keeping the gas nozzle close to the work and recessing the contact tube within it.

Argon shielding gas generally did not permit the use of arc lengths of less than $\frac{1}{4}$ in., since short circuiting and gross instability developed when the wire tip was forced closer to the work. All other gases permitted the electrode tip to be driven below the work surface without difficulty. The maximum arc length that could be studied was determined either by the maximum voltage output of the power supply or the field of view of the apparatus used to project the magnified arc image. In general, the longest arcs were $\frac{5}{8}$ in. and were used only because of academic interest.

Current maxima and minima were imposed by the wire diameter and stick-out; these limitations will be discussed later.

The equations that express the influence of the process variables are valid only within the restrictions of this study. They can, however, be extended somewhat with reasonable accuracy; gross extrapolations are useful only to indicate the trends to be expected.

Anode Heating

According to many physicists,[3,4] the anode is not a direct source of positive ions to the arc; on the contrary, because of its high temperature, it emits free

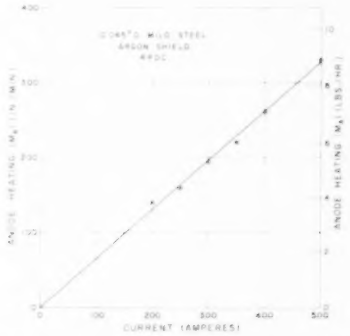

Fig. 4 The effect of welding current on anode heating as measured by melting rate

electrons. These electrons do not have sufficient energy to overcome the attractive forces of the anode, and so, with other electrons from the arc stream, they form a very thin electron cloud immediately about the electrode. As a result of the difference in potential between the electron cloud and the anode, a steep voltage gradient develops that is called the anode drop. The magnitude of this drop is only a few volts, but it occurs across such a very short space that the voltage gradient measured in volts per inch is extremely high. Electrons entering this field from the arc are accelerated to very high velocities and develop considerable kinetic energy that is converted to heat at the point of impact with the anode.

Additional heat energy also is transferred to the anode when the impacting electrons are absorbed by the metal lattice. This energy can be considered an "energy of condensation," and a measure of it is the thermionic electron work function of the anode material.

The heat developed by these basic reactions has been represented mathematically by:

$$H_a = cV_a + \phi I \qquad (1)$$

where

H_a = heat generated by the anode reactions.
V_a = anode drop.
ϕ = anode thermionic work function.
I = current.

All of this heat is not available to melt and vaporize the electrode. Some of the attracted electrons dissipate their energies by ionizing the gas molecules and metal vapors boiling off the anode; these reactions are conceded by some to be a major source of positive ions within the arc. Losses also can occur by radiation and conduction through the electrode and the shielding gases, but these factors can be shown to be negligible in most cases.

According to eq 1, anode heating would be expected to be a function of current, anode drop and the electrode work function. It says nothing about

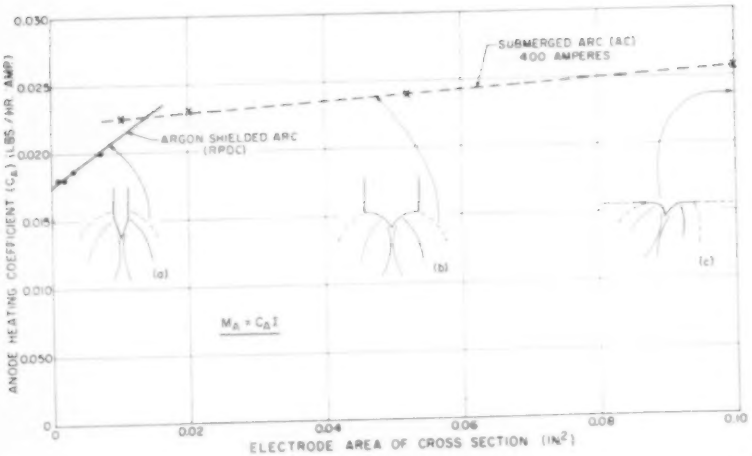

Fig. 5 Relationship of the coefficient of anode heating to the electrode area of cross section

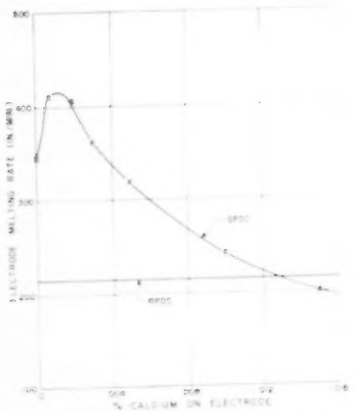

Fig. 6 Change in electrode melting rate at straight-polarity direct current due to the presence of calcium on its surface as calcium chloride

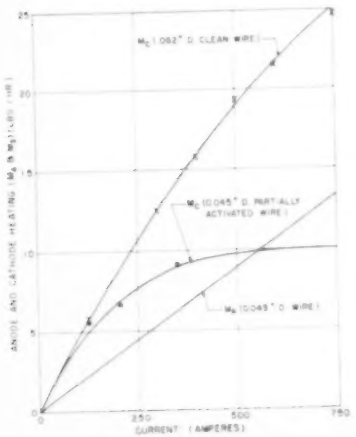

Fig. 7 Dependence of melting rate due to cathode and anode heating on the magnitude of welding current (mild-steel electrode, argon + 1% oxygen shield)

any other variables, such as the shielding gas, having any effect upon heating of the anode.

Effect of Welding Variables on Anode Heating

The contribution of anode heating to the melting of electrodes at a given current was obtained by isolating the contribution of the electrical-resistance heating of the electrode; that is, by determining the melting rate with zero electrode extension. Maintenance of an arc under such circumstances is not practical, but the hypothetical melting rate expected with no electrode extension can be determined by measuring the melting rate at various extensions and extrapolating the resultant curves to a zero extension as already demonstrated with Fig. 2. It is a plot of the electrode melting rate at different electrode extensions and welding currents. Since the melting rate at a given level of current is seen to increase linearly with stick-out, the determination of melting rate with no stick-out can be done easily by extrapolating the curves back to zero. The rate of melting with no stick-out is due almost entirely to anode heating; radiation heating may have a slight affect.

When the rates of melting due to anode heating (the rates at zero extension) are plotted as a function of welding current, curves similar to that shown in Fig. 4 are obtained. This figure shows that the value of anode melting rate, M_a, is directly proportional to the welding current and can be defined by the general equation:

$$M_a = C_a I \qquad (2)$$

This equation is very similar to the theoretical equation (1); C_a, the slope of the curve, is related to the anode drop, V_a, and the electrode work function, ϕ. Later information will demonstrate that M_a is actually the result of anode heating only; it is independent of other process variables such as arc length and electrode extension.

The coefficient, C_a, is dependent upon changes in the specific heat of the electrodes and, therefore, their chemistry. It also is dependent upon the electrode diameter as shown in Fig. 5. This dependence seems to be caused by changes in the effective anode area with changes in the electrode diameter. If this is the case, the efficiency of heat transfer from the anode is reduced as the anode area is restricted by the dimensions of the electrode.

Gas-shielded welding electrodes are generally small in diameter and, during welding, their tips develop a shape similar to that sketched in Fig. 5*a*. The base of the tapered tip in this case has a diameter equal to that of the electrode. Because of its conical surface, the effective anode area is greater than that calculated simply from the cross-sectional electrode area.

Apparently, the effective anode area increases with electrode diameter, and simultaneously, a greater efficiency of anode heating achieves higher melting rates. The increase in heating efficiency as measured by the anode-heating coefficient, C_a, is illustrated by the solid curve of Fig. 5. However, this dependence on the anode diameter does not seem to continue indefinitely. After some critical diameter, a change occurs in the slope of the curve relating C_a to diameter. At this point, the electrode tip assumes a shape similar to that sketched in Fig. 5*b* wherein the arc plasma is seen to envelop the entire electrode cross section. Further increase in electrode diameter does not result in an increase in anode area, and the efficiency of heating as measured by C_a increases only slightly.

The dashed curve of Fig. 5 is taken from the work of Wilson, *et al.*,[1] and is based upon data obtained with alternating-current submerged arcs. Although not completely appropriate to this discussion, their data demonstrate the trend with large diameter electrodes; i.e., a relatively small dependence of electrode heating on electrode size.

The arcs typical of Fig. 5*c* are those found experimentally with $\frac{1}{4}$-in. welding electrodes in argon shields and with the even larger electrodes used for consumable-electrode arc melting in argon atmospheres at atmospheric pressure.

Electrode heating due to anode reactions was found to be independent of the electrode extension. Initially this independence was assumed for the derivation of eq 1 for anode energy; subsequent experiments showed this assumption to be valid.

Shielding Gases

A number of experiments tried with a variety of gases and gas mixtures showed

that anode heating is not influenced by the composition of the shielding gas. Although changes in gas composition caused marked changes in metal transfer, weld soundness and weld shape, the changes in the electrode melting rate were quite small. Typical data from such experiments are presented in Table 1. The reported differences in melting rate are felt to be due primarily to experimental error, since some difficulty in measuring arc length was found. This is particularly true with the violently agitated tip that commonly occurs with shielding gases such as nitrogen and carbon dioxide.

That anode heating is independent of the shielding gas is not surprising, particularly in the light of eq 1. The anode heating is due, primarily, to its adsorption of the electrons emitted by the cathode or from within the arc plasma. Positive ions and other particles originating from different gases appear to influence anode heating to the same degree.

Activation

Certain coatings have been shown[5] to have a strong effect upon the melting rate of an electrode when it is the negative pole. This effect has been attributed to a reduction in the effective work function of the electrode surface. According to eq 1, a reduction in work function also would be expected to reduce the anode heating and cause a reduction in melting rate. However, the data in Table 1 show that cesium treatments produce no appreciable effect upon the anode melting rates, even though a substantial reduction in work function is known to occur. Since a reduction in work function allows electrons to be released more easily from the anode, a stronger field might be produced at that pole to increase V_a and thus compensate for the reduction in ϕ.

Table 1—Effect of Shielding Gases and Electrode Surface Condition on Electrode Melting Rate with Reverse-Polarity Direct Current

Shield	*Surface condition*	*Melting rate, in./min*
(Mild steel; 350 amp, $^5/_{16}$-in. diam, $^3/_4$-in. extension)		
Argon	Clean	225
Argon	Cesium treated	215
Helium	Clean	230
Helium	Cesium treated	235
Nitrogen	Clean	225
Nitrogen	Cesium treated	225
Carbon dioxide	Clean	235
Carbon dioxide	Cesium treated	230
(Aluminum; 300 amp, $^5/_{16}$-in diam, $^3/_4$-in. extension)		
Argon	Clean	274
Helium	Clean	282
Air	Clean	280

Review

In review, the anode energy that is available for melting the electrode with reverse-polarity arcs increases with the electrode diameter and the welding current, but is independent of the shielding gas, activation of the electrode and the electrode extension.

Cathode Heating

The cathode supplies a large portion of the electrons that are needed to conduct welding current through the arc stream. In much the same way that the anode is surrounded by unlike charges (electrons), the cathode is surrounded by a positive charge. Whether this charge is due to an excess of positive ions or a dearth of electrons is not really known. Nevertheless, this sheath acts to accelerate positive ions to the cathode with an increase in energy that is proportional to the potential fall, V_c, at the cathode surface. These ions supply energy ($i_p V_c$) for heating the cathode, where i_p is the positive ion current. The same positive ions also can supply energy to the cathode when they become neutralized at its surface; this additional energy is proportional to the ionization potential, V_i, of the particular ion in question and is given as ($i_p V_i$).

Energy is lost by the cathode through the release of electrons that maintain emission; this energy term is given by ($i_e \phi$) where i_e is the thermionic electron current and ϕ is the thermionic work function of the electrode. A certain amount, too, is lost by neutralization of the positive ions by electrons at the cathode. This energy is given by ($i_p \phi$).

The energy available to heat and consequently melt the electrode is seen, then, to be a summation of the energy absorbed and released by the above reactions. Their interrelationship can be shown in an admittedly over-simplified equation as follows:

$$H_c = i_e V_c - i_e \phi + i_p V_c - i_p \phi = i_p V_c - \phi + i_p V_i - i_p \phi \quad (3)$$

The positive ion current is made up of ionized metal vapor and gases supplied for shielding. The total current, I, is made up of fractions f_m, f_m and f_g carried by ionized gas, ionized metal and electrons respectively with the total of these fractions being equal to one.

By substituting these fractions:

$$i_m = (f_m + f_m) I$$

and

$$i_e = f_e I$$

into equation three, a general equation for cathode heating is evolved as follows:

$$H_c = [(f_g + f_m)(V_c - \phi) + f_g V_{ig} + f_m V_{im} - f_e \phi] I \quad (4)$$

V_{ig} and V_{im} are the ionization potentials of the gas and metal ions respectively.

Some authorities[4] feel that an arc discharge depends largely upon thermionic emission from the cathode. This is unquestionably the case with refractory metals such as tungsten since these metals can supply adequate electrons at their boiling temperature and most of the arc current satisfies the Richardson-Dushman equation:

$$I = AT^2 e^{-\frac{\phi}{kT}}$$

where

T = absolute temperature of the electrode.
A = constant characteristic of the electrode.
I = thermionic electron current density at the point of emission from the electrode.

Using tungsten, the fraction of current due to electrons, f_e, is very high, but the fraction of positive ions assisting the transfer of current is adequate only to keep the electrode sufficiently hot to supply the required flow of thermionic electrons.

The structural metals, on the other

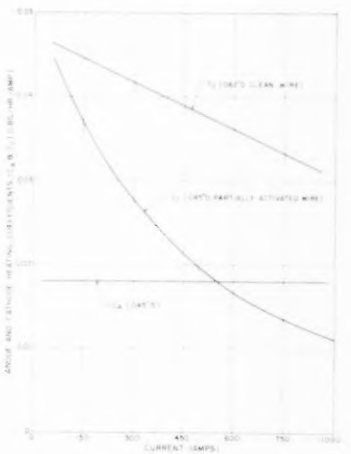

Fig. 8 Change in the cathode-heating coefficient due to the magnitude of welding current (mild-steel electrode, argon + 1% oxygen shield)

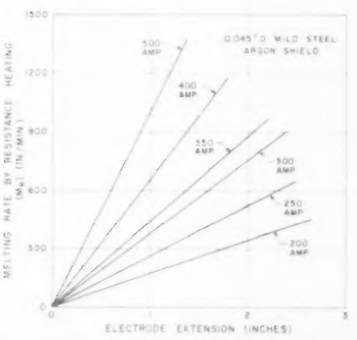

Fig. 9 Effect of welding current and electrode extension on the electrode melting rate due to its electrical-resistance heating

hand, are incapable of supplying sufficient electrons to sustain an arc by thermionic emission because of the low boiling temperature of the electrode. Conceivably, heating on a micro-scale level could safely raise the temperature of the cathode surface well above its boiling temperature without its destruction, allowing thermionic electrons to be released. A very thin cathode sheath also could raise the voltage gradient at the cathode surface to millions of volts per inch and remove electrons from the surface by a phenomenon termed field-emisson.

Although micro-reactions of thermionic or field-emission character could maintain welding arcs with ostensibly cold-cathode materials, it is not likely in view of experimental data. More probably, both electrons and positive ions are needed to conduct current, and the ratio of positive ions to electrons is determined by the work function, boiling temperature, and shape and area of the cathode surface. In view of this hypothesis, a change in work function or boiling temperature would be expected to change the fraction of current carried by the electrons, the number of which is given by the Richardson-Dushman equation. Therefore, a reduction in work function or an increase in temperature will increase the fraction of electrons, f_e, at the expense of the ionized gas and metal vapors, f_g and f_m, and cause the cathode heating H_c to decrease as demonstrated by eq 4. An increase in cathode area would permit the total electron current to be greater for the same electron current density and cause H_c to be lowered.

A dependence of melting rate upon work function and boiling temperature has been noticed,[5] and the ratio of positive ions to electrons conducting current has been used to explain some of the aspects of metal transfer with straight-polarity direct-current welding.

The same hypothesis can be used to explain a higher voltage gradient at straight polarity than reverse polarity within the plasma of an argon-shielded mild-steel welding arc. Using straight-polarity where the cathode area is severely limited by the size of the electrode, an arc-stream gradient of 75 v per in. was found with a 300-amp arc in argon. However, the same 300-amp arc at reverse polarity required only 20 v per in. between the electrodes. The summation of the anode-plus-cathode drops was the same in both cases, proving the cathode drop to be independent of the area. If the cathode temperature at the plate is assumed to be the same as on the wire, more electrons will be available from the broad cathode at the plate with reverse polarity than the wire; more positive ions must be developed within the arc stream to maintain the straight-polarity arc. A higher voltage gradient at straight polarity is seen to indicate that the additional energy is needed to produce and conduct more positive ions in order to maintain the arc with fewer electrons from the cathode.

The above explanations are given in an attempt to explain the reactions at the cathode using a classical approach of motion and energy. It is because the classical approach is not wholly correct that a satisfactory explanation of arc phenomena in general cannot be developed. In all probability, new concepts of the physics of extreme temperatures, confined volumes and restricted areas will be needed to explain all of the phenomena noted in the high-current welding arcs.

Electrode Composition and Activation

Energy is supplied to the cathode by positive ions that are accelerated by the steep voltage gradient through the cathode sheath. Electrons are supplied by the cathode to neutralize these positive ions and to conduct a portion of the welding current. When these electrons are released, energy is absorbed to cause cooling of the electrode. Because of this, any reaction that causes the number of electrons supplied by the cathode to increase would reduce the useful heat energy developed. For a given metal, an increase in electron emission can be achieved by lowering its work function. When this happens, the ratio of positive ions to electrons within the arc plasma is probably lowered and less energy is released at the cathode.

Activation of the electrode at straight polarity can be accomplished with metals or their compounds that lower the electrode work function.[6, 7] This treatment was developed to regulate the transfer of metal from the electrode and weld penetration with straight-polarity direct-current arcs, and to sta-

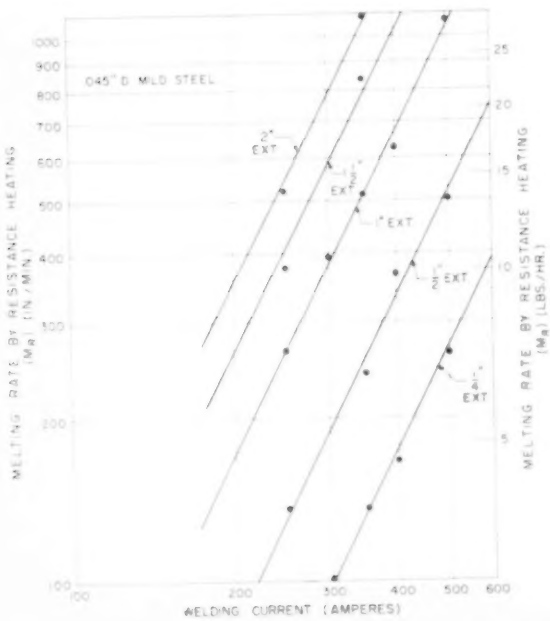
.045" D MILD STEEL
MELTING RATE BY RESISTANCE HEATING (MR) (IN/MIN)
MELTING RATE BY RESISTANCE HEATING (MR) (LBS/HR)
WELDING CURRENT (AMPERES)
EXT

Fig. 10 Effect of welding current and electrode extension on the electrode melting rate due to its electrical-resistance heating

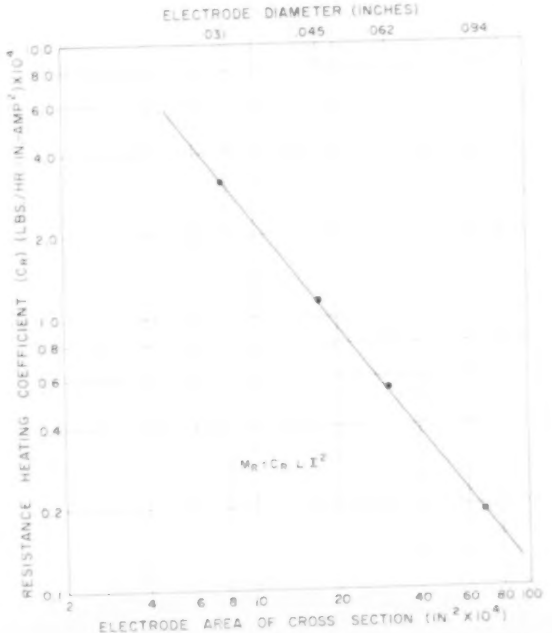

Fig. 11 Dependence of the electrical-resistance heating coefficient upon the electrode cross-section area

bilize alternating-current arcs. Since these effects are associated with a reduction in work function, it is necessary to tolerate an unavoidable reduction in melting rate.

This reduction is illustrated in Fig. 6 which shows that the melting rate of a steel electrode at straight polarity is reduced with an increased concentration on calcium on its surface. The calcium causes a marked reduction in work function that is dependent upon its concentration up to some critical amount, beyond which the decrease is not so great. The amount of change is dependent upon the composition of the electrode as well as the activating material since interaction between them affects the efficiency of activation and the change in work function.

Effect of Shielding Gas

Shielding gases might be classified as falling within one of two groups; i.e., those that are oxidizing in character and those that are not oxidizing. With the first group, it is possible for an iron-oxide layer to form on the electrode surface just prior to its entrance into the arc regions, causing the electrode to supply more thermionic electrons to the arc. Mixtures of argon and oxygen or carbon dioxide fall into this classification of oxidizing gases.

Neutral gases such as helium, which fall into the second group, are very similar to each other in behavior; they develop equivalent melting rates as shown in Table 2 since they do not affect the thermionic properties of the electrode.

The melting rate shown for carbon dioxide, an oxidizing gas, is higher than one would expect in lieu of previous discussions. This gas does reduce melting rate when added in dilute amounts to argon. However, excessive concentrations cause a reversion to globular transfer and, simultaneously, a slight increase in melting rate.[3] These reversions are believed to be the result of a thermal dissociation of the molecular gases and an increased positive-ion bombardment of the cathode.

It is interesting to note that melting rates of mild steels in inactive gases are independent on the ionization potential of these gases; i.e., the melting rate of 400 in. min with helium having an ionization potential of 24.6 electron volts is no different from that of argon with an ionization potential of 15.75 electron volts. This is contrary to the difference that would be expected in view of eq 4 unless the losses due to evaporation of the neutralized gases are equal to the energy of neutralization, a postulate that is unlikely, or a difference in f_v and f_i is developed with the various gases.

Table 2—Effect of Shielding Gases in Electrode Melting Rate with Straight-Polarity Direct Current

Gas	Melting rate, in./min
(Mild steel, 350 amp, $\frac{5}{32}$-in. diam, $\frac{3}{4}$-in. extension)	
Helium	400
Argon	395
Nitrogen	370
Carbon dioxide	370

Effect of Welding Current

Cathode heating of specially cleaned mild-steel electrodes was found to be related to the welding current. The melting rates due to such heating were, for all practical purposes, linearly dependent upon current as shown by the uppermost curve of Fig. 7. The slope of this melting-rate curve is almost twice that developed for the same electrode caused by anode heating. Although the lowest curve in Fig. 7 is not for the same electrode diameter, it does allow a comparison of the order of magnitude of anode and cathode heating. Activation of the electrode causes a considerable deviation of melting rate from that for the untreated electrode and this deviation is greater at higher currents as illustrated in Fig. 7 by the curve labeled M_a for a partially activated wire. This deviation would be even greater for a fully treated electrode. These changes are due to the fact that the degree of emission from a cathode electrode is affected not only by the amount of compound on its surface, but by the magnitude of the welding current as well. Their effect on the cathode-heating coefficient is shown in Fig. 8. It demonstrates the decrease in C_c at progressively increasing currents and the effect of activation on this rate of decrease. The anode-heating coefficient already has been shown to be independent of the amount of activation.

As a result of the reduction in the magnitude of the cathode-heating coefficient with increasing current, it is possible to achieve lower electrode melting rates with straight-polarity arcs than reverse polarity after the current exceeds some critical value. This is demonstrated in Fig. 7 by the two lower curves. They show the melting rate of a particular electrode to be greater when it is the cathode, if the current is below 550 amp. However, when the current exceeds 550 amp, the electrode melting rate is greater when it is the anode. This change is due to the rapid reduction of C_c that is caused by increasing current. Figure 8 shows C_c to be very high at low currents, but that it decreases rapidly with current while C_a is fixed. Consequently, the two curves intersect at the 550-amp level, and C_a subsequently exceeds C_c.

Effect of Electrode Extension

The cathode-heating coefficient has been shown to be affected by the thermal distribution at the electrode tip since this controls the area and degree of electron emission. Additional evidence for the influence of electrode heating is provided by the fact that the coefficient also is dependent upon the electrode extension; it, too, would have an effect upon the temperature distribution at the electrode tip.

An increase in extension was found to cause a decrease in cathode heating, the amount of this decrease also being dependent upon current. The decrease in cathode melting, M_c, for a clean, mild-steel cathode electrode in argon was shown to be $0.0025\,LI$ (lb/hr); where L is stick-out in inches and I is current in amperes. This change in melting is not universal; obviously, the amount of change due to stick-out also will be dependent upon any activation treatment that modifies cathode heating. Probably, it is sufficient to mention only that such an effect does exist and that calculations for melting rate are infinitely more complex with straight-polarity than with reverse-polarity direct-current welding.

Review

Cathode heating, then, is similar to anode heating in that it is dependent upon current. This dependence approaches linearity, however, only with an absolutely clean cathode surface. As a result of activation with alkali, alkaline-earth and rare earth metals, cathode heating is a nonlinear function of current. Cathode heating also has a nonlinear relation to stick-out, but the departure from linearity is substantially less than its relationship to current. Wire diameter is expected to have an effect on cathode heating, but this hypothesis cannot be proved because of the other effects which are difficult, if not impossible, to hold constant. Cathode heating is dependent upon the shielding gases if they are oxidizing in character. Other gases do not seem to have any effect upon melting rate.

Electrical-Resistance Heating

The flow of electrons through solid metals is restricted by internal magnetic fields that are characteristic of the particular metal alloy and its metallurgical history. These restrictions to the flow of electricity are overcome by supplying sufficient voltage at the terminals of the conductor. The voltage needed to force the flow of a given amount of current is directly proportional to the electrical resistance and is defined by Ohm's Law:

$$E_R = \rho \frac{L}{A} I$$

where

ρ = electrical resistivity,
L = conductor length,
A = cross-section area of the conductor,
I = current flowing in the conductor.

This equation needs no explanation other than to emphasize that ρ is not really a constant but is strongly dependent upon the temperature and composition of the conductor.

When the conductor being considered is a welding electrode, this voltage drop times the current flow is the heating energy due to the electrode's resistance to the flow of current and is given by:

$$H_E = \rho \frac{L}{A} I^2 \qquad (7)$$

It increases with the electrode extension, a reduction in cross-section area of the electrode, and the square of the welding current. The resistivity, ρ, is dependent on temperature and also determines the rate at which heat is generated within the electrode; its average value is dependent upon the temperature distribution within the electrode.

Effect of Electrical-Resistance Heating

The actual contribution of electrical-resistance heating to melting of the electrode can be obtained by subtracting from the measured melting rate, the melting rates due to energy from the anode or cathode energy plus those from any other sources. The measured melting rates shown in Fig. 2 for various extensions and currents are the summation of melting rates produced by anode and resistance heating effects. The contribution of anode energy at each level of current is found by extrapolating to zero extension the effect of extension on melting rate. The values of anode heating with different currents have been presented in Fig. 4.

By subtracting the melting rates produced by anode heating from the data similar to those plotted in Fig. 2, the contribution to melting of resistance heating alone is found. These melting rates are dependent upon current and electrode extensions as shown in Fig. 9. It is interesting to note that the melting rate is directly proportional to stick-out as predicted by eq 7.

This linearity, although satisfying, is perhaps surprising because the average temperature and resistivity of the electrode might be expected to increase with extension, and a somewhat exponential curve would develop. This exponential characteristic does, in fact, develop with excessive values of current when the electrode extensions are so long that they are out of range of practicability with the type of welding under discussion. The fact that these deviations from linearity are not observed with extensions of less than a few inches is attributed to the fact that the average temperature of the electrode does not change. As the electrode extension is increased, its rate of feed for a given current also must increase if the arc length is not to change. This requirement of an increase of wire feed speed will compensate for the longer extension so that a given increment of the electrode senses this current for substantially the same length of time as with short extensions. Consequently, the average temperature distribution and resistivity over fractional lengths of the electrode do not seem to change.

Effect of Current

Again referring to Fig. 9, the melting achieved by resistance heating is seen to be dependent upon current. The melting rate, M_E, due to resistance heating, and current are not, however, related by any linear function. However, a straight-line relationship can be produced by plotting M_E as a function of current on logarithmic coordinates. A re-plot of the data of Fig. 9 on logarithmic coordinates is given in Fig. 10 with M_E as a function of current with various parameters of electrode extension. In this case, with 0.045-in. diam wire, the data satisfy adequately the equation

$$M_E = 42.1 \times 10^{-4} LI^2 \text{ in./min} \qquad (8)$$

where

L = stick-out in inches.
I = current in amperes.
M_E = resistance heating contribution to the total melting rate.

This equation demonstrates again that M_E is directly dependent upon the electrode extension. It also shows that the melting energy increases as a function of the current squared as predicted by eq 7. In simplified form, the above equation can be written as

$$M_E = C_E LI^2 \qquad (9)$$

where

C_E = constant of proportionality that is dependent upon electrode diameter and the electrode resistivity.

Effect of Electrode Diameter

Since the total resistance of a conductor is dependent upon its cross-sectional area, the constant of proportionality, C_E, would be expected to change with its diameter. This was found to be true; typical values of C_E for a mild-steel electrode are listed in Table 3.

Table 3—Values of C_E for Various Diameters of a Mild-Steel Electrode

Diameter, in.	C_E in./min amp² in.	C_E lb/hr amp² in.
0.030	260.0×10^{-4}	313.0×10^{-4}
0.045	42.1×10^{-4}	114.0×10^{-4}
0.062	10.5×10^{-4}	54.7×10^{-4}
0.093	1.62×10^{-4}	19.2×10^{-4}

Obviously the relationship between C_E and diameter is not linear. However, when the values of C_E are plotted as a function of the area of cross section on logarithmic coordinates, it is found that a definite exponential relationship between the two does exist. This is demonstrated by Fig. 11 which shows that C_E decreased with increasing areas, the curve being defined by:

$$C_E = \frac{3.69 \times 10^{-5}}{A^{1.26}} \text{ lb/hr in. amp}^2$$

or

$$\frac{5.0 \times 10^{-5}}{D^{2.52}} \text{ lb/hr in. amp}^2 \qquad (10)$$

Inserting this value for C_E into eq 8 yields:

$$M_E = \frac{3.69 \times 10^{-5}}{A^{1.26}} LI^2 \text{ lb/hr}$$

or

$$\frac{5.0 \times 10^{-5}}{D^{2.52}} LI^2 \text{ lb/hr} \qquad (11)$$

This equation shows the effects of the

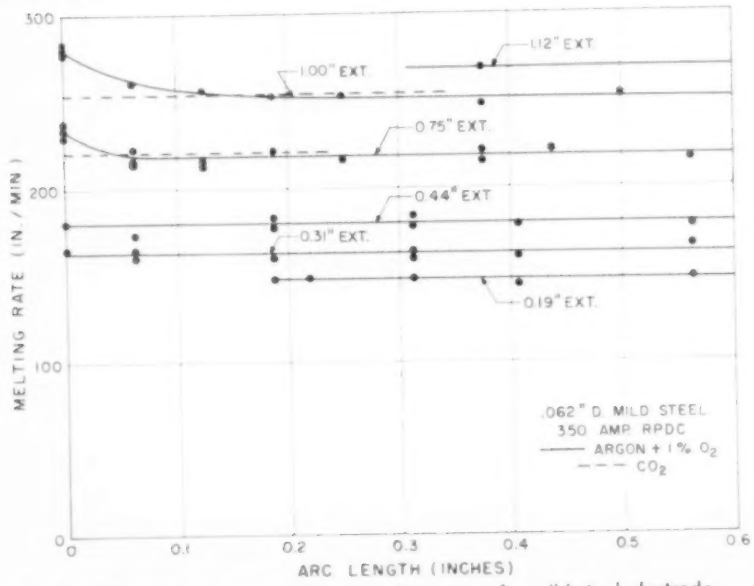

Fig. 12 Effect of arc length upon the melting rate of a mild-steel electrode

electrode area, extension and current upon the amount of melting caused by resistance heating.

Comparing this with the theoretical equation shows the constant C_R to have the dimensions of electrical resistivity, ρ. It also shows that the empirical relationship does not compare exactly with the theoretical, since M_R is shown to have a slight exponential relationship with the cross-sectional area, although in theory the relationship should be direct. This probably is due to a variation in the average value of resistivity brought about by a change in temperature distribution along the electrode as the cross-sectional area changes. This is more likely than expecting ρ to remain fixed despite changes in area. Equation 11, however, was derived on the basis of a constant resistivity; the fact that the resistivity is not constant would be reflected in the exponential character of A. A relationship between ρ and A could be found, but it would serve only to complicate the equation. Therefore, even though it is not mathematically satisfying, the equation was left standing to facilitate melting-rate calculations.

Effect of Electrode Composition and Temper

The value of C_R of eq 10 is strongly dependent upon the resistivity of the electrode being used. In the case of a mild-steel electrode of $\frac{1}{16}$ in. diameter, it has the value of 54.7×10^{-6} lb hr amp^2 in. C_R of an aluminum electrode of the same diameter has the value of 9.8×10^{-6} lb hr amp^2 in. Differences also are to be expected with various alloys of a given type of material. As a result of the relatively small value of ρ for aluminum, these electrodes are not as sensitive to changes in extension; manipulations of the welding gun during manual operations does not cause great changes in arc length. This is not true with steel, particularly with electrodes having relatively small diameters since the dependence on extension is so great that changes in the position of the welding gun would cause the arc length to change. The extent of such changes will, of course, be determined to a large degree by the volt-ampere characteristic of the power supply being used.

The degree of cold work developed in the electrode during its fabrication has been found to have an effect only when excessive and then only with extensions that are impractically short. Very severe drawing of the wire will cause the value of C_R for a given diameter and composition of a ferrous electrode to increase somewhat. This effect is not considered important since such electrodes are not practicable for welding, the wire cast is difficult to control and the contact tube life can be shortened appreciably.

Radiation Heating

The arc plasma is known to be extremely hot; estimates of its temperature by different investigators range from 6000 to 12,000° C. These high temperatures are sufficient to cause the thermal ionization of the shielding gases and metal vapors which is needed to form a conductive medium between the electrodes. Because of this localized source of energy, both electrodes would be expected to receive considerable heat for melting from it. The weld pool, too, might be expected to be a source of radiant energy for melting the electrode wire. Apps and Milner[5] used calorimetric techniques to demonstrate that tungsten electrodes receive considerable energy from the arc stream. These results are not necessarily applicable to gas-shielded arcs with consumable electrodes since they are quite different from those formed with nonconsumable tungsten electrodes. The current densities are greater with the consumable electrodes, the plasma configurations are different from those encountered with tungsten electrodes, and metal is transferred from the electrode. These differences would cause sizeable change in the mechanisms of heat transfer.

Effect of Arc Length

Studies incorporating changes in the apparent arc length have shown that radiation has only a very slight effect upon the melting rate of steel. Figure 12 is typical of the general results; it shows the influence of arc length upon melting rates of a $\frac{1}{16}$-in. diam mild-steel electrode at a fixed current, and various fixed electrode extensions. Changes in arc length produce only minor changes in melting rate, particularly with medium arc lengths and short electrode extensions.

In argon, the melting rate seems to increase with short arc lengths when the electrode stick-out is in excess of $\frac{3}{4}$ in. However, these results might be due to changes in the shape of the electrode tip or some other geometric factor, since the melting rate in an atmosphere of CO_2 was not increased under the same circumstances.

Aluminum electrodes are decidedly more sensitive than steel to differences in arc length as shown in Fig. 13. Although still independent of arc length with long arcs, the melting rate increases with decreasing arc lengths when normal arcs and electrode extensions are used for welding. This increase in melting rate is very slight at first; a 0.25-in. change in the length produces only a 5% change in melting rate. However, when the arc length is shortened to below 0.03 in., a great change in melting rate is produced. It seems that a number of effects influences the results with aluminum since three distinctly different slopes of melting rate vs. arc length are found. No good explanation for these changes in slope can be offered at this time.

Effect of Shielding Gas

The various shielding media used with consumable-electrode arcs have widely different voltage gradients for any given level of current. Carbon-dioxide shields, for example, have voltage gradients on the order of 45 v in. while argon produces 20 v in. These differences in voltage cause comparable changes in the power supplied to the arc streams and, conceivably, the radiant energy available. Nevertheless, the changes in melting rate with various shielding gases could not be measured. Some of the

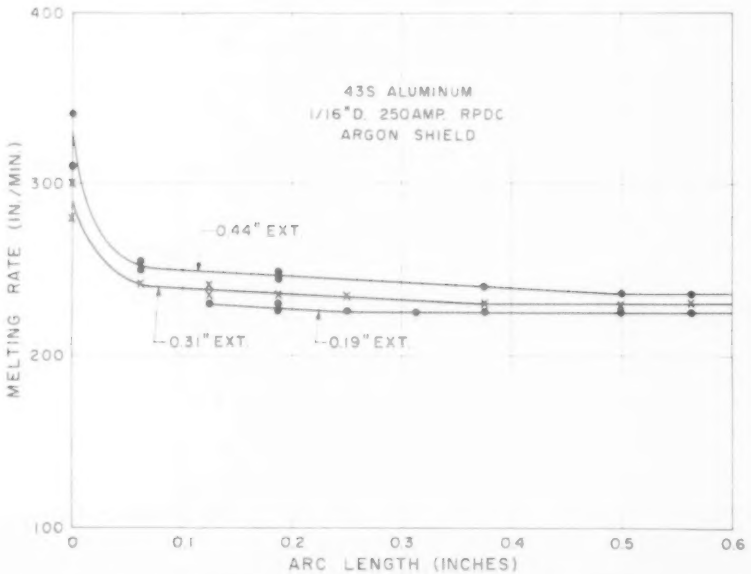

Fig. 13 Effect of arc length on the melting rate of an aluminum electrode

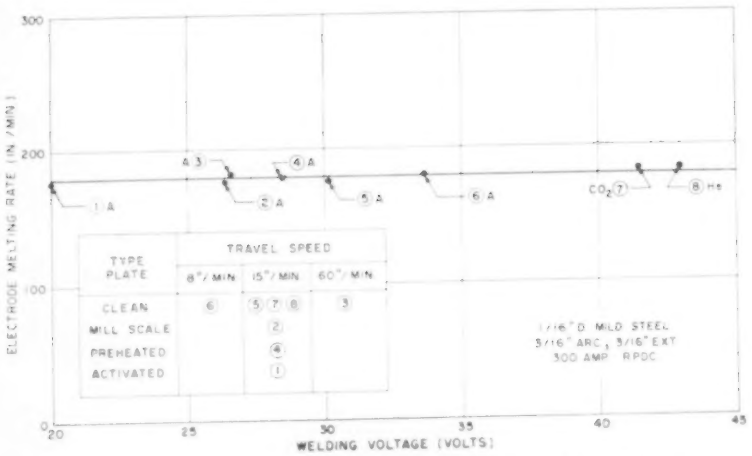

Fig. 14 Independence of electrode melting rate on the welding voltage

expected results might have been masked by differences in metal transfer with these gases. However, these data supply additional evidence to support the hypothesis that melting rate is independent of radiation heating, at least within experimental measurement and particularly when compared with the other sources of energy for melting.

Effect of Radiation from the Weld Pool

Since the sizes of the arc crater and weld pool are inversely proportional to travel speed, the amount of energy supplied by this source for melting would be expected to decrease with increasing travel speeds; i.e., the melting rate should decrease with increasing travel speeds. This effect was not found with steel. Melting rates for constant current and constant stick-out were independent of travel speeds; at least within the range of from 5 to 80 in. min.

Effect of Arc Voltage

A number of factors has a decided influence upon arc voltage. They include the shielding gas, arc length, travel speed, surface impurities on the plate and activation of the electrode. Considerable work with energy input to the covered-electrode arc, measured basically as volts times current per unit travel speed, has shown that cooling rates, size of the heat-affected zone and maximum hardness of the heat-affected zone are influenced by the energy input.[3] One might expect, therefore, that melting rates too, would be affected by the arc power. Previous paragraphs have indicated that these results are not always as expected, but they have not discussed the effect of arc power as such.

In order to resolve this point, a series of experiments was run with reverse-polarity direct-current arcs in argon, helium and carbon-dioxide shields while maintaining a fixed current, arc length and wire extension. The arc voltage was changed by varying the travel speed, condition of the plate surface and activation of the electrode. Although these changes caused the arc power to vary from 6000 to 12,000 w, they produced no change in the electrode melting rate outside the limits of experimental error as shown in Fig. 14. The same results could not be expected at straight polarity since the activating materials would change the emission characteristics of the cathodic electrode. These results supply additional proof to the hypothesis that the electrode receives very little radiant energy from the arc stream. Equally important, they imply that the workpiece receives only a small amount of energy by radiation from the arc. Consequently, the concept of arc power as measured by volts times amperes does not necessarily measure the energy received by the work surface. If anything, the energy from short arcs having low voltages is probably greater than that received from long arcs having high voltages.

Possibly the most important conclusion that can be drawn from the data of Fig. 14 is that arc voltage should not be used to define a welding condition; the voltage is apt to be dependent on too many factors that cannot be held fixed. Hence those conditions such as arc length that are critical will vary if voltage is fixed. Actually, the arc voltage is not an independent variable; the factors that are most important in defining a particular welding condition are the current, electrode extension and arc length.

Discussion

The above results have been presented to show that radiation from the arc plasma and the weld have only a negligible effect upon the electrode melting rate. Arc length, travel speed, shielding gases (if they do not affect the electrode emission at straight polarity) and arc voltage have no practicable effect upon the melting rates of mild-steel electrodes if all other conditions remain fixed. The same picture does not necessarily exist with other electrodes; aluminum was shown to be more affected by differences in arc length than was steel. However, radiation effects upon the consumption of welding electrodes are not at all as great as those other factors previously considered.

Anode, cathode, electrical resistance and radiation heating have been considered as the sources of heat that conceivably could control the melting rates of welding electrodes. Although the investigation was primarily concerned with mild-steel electrodes consumed in gas-shielded metal-arc welding, the results are expected to be applicable, in principle, to other metals and processes. Of the four heat sources examined, only radiation heating was found to have a negligible effect upon the melting of electrodes.

Electrical reactions at the anodic and cathodic electrodes were shown to supply the greatest proportion of energy for the most frequently used conditions of gas-shielded arc welding. They are dependent primarily upon the welding current, although electrode diameter also is important. Anode heating was shown to be unaffected by shielding gases, electrode extension or other factors. The cathode heating on the other hand is affected by the electrode extension and the presence on the electrode surface of various compounds of alkali, alkaline earth and rare-earth metals.

Resistance heating affects the rate at which electrodes are melted. It varies with electrode diameter, electrode extension, welding current and any metallurgical or chemical effect that modifies electrical resistivity.

An empirical equation was developed that shows the quantitative relationship among electrode melting rate, anode heating and resistance heating for reverse-polarity direct-current welding. It is as follows:

$$M_{R_0} = (0.017 + 0.37\,A)I + \frac{3.69 \times 10^{-5}}{A^{1.26}} LI^2 \text{ lb/hr} \quad (12)$$

This particular equation is valid only for a particular mild steel. The constants are dependent upon the composition of the electrode; the value of the exponent is probably equally dependent upon the electrode material. The general form, however, is applicable for other metals.

Figure 15 demonstrates the relative importance of anode and resistance heating. The anode energy increases linearly with current, but is independent of the electrode extension. Resistance-heating energy, on the other hand, is shown to be dependent upon electrode extension as well as the current; because of this, higher melting rates are achieved with 1-in. extensions than $\frac{1}{4}$ in. This figure demonstrates the need for listing the exact value for electrode extension

Table 4—Anode and Resistance-Heating Coefficients

(¼-in. diam electrodes)

	C_a (lb/hr amp)	C_r (lb/hr-amp^2-in.)
Aluminum	1.2×10^{-3}	9.7×10^{-5}
Mild steel	1.86×10^{-3}	54.7×10^{-5}

when welding conditions are specified; particularly when high currents are being used.

The importance of extension is minimized with high-conductivity metals such as aluminum. Anode heating is comparable to that with steel as shown in Table 4, but the resistance-heating factor is considerably less. It is for this reason that changes in the position of the welding gun have a much smaller effect upon the arc length with aluminum electrodes; i.e., the self-regulation of the arc is greater.

The melting rate with straight-polarity direct current is so dependent on a number of other factors, such as the electrode surface condition and the composition of the shielding gas, that general relationships as precise as those shown earlier for reverse polarity are very difficult to obtain. The effect of electrode diameter could not be established, but for a given diameter of mild-steel electrode, the following relationship for a particular untreated electrode having a diameter of $\frac{1}{16}$ in. was found:

$$M_{s_p} = (0.049 - 1.8 \times 10^{-5} I)I = 0.0625I + 54.7 \times 10^{-5} LI^2 \text{ lb/hr} \quad (13)$$

The melting rate with straight polarity normally is greater than that with reverse-polarity direct current. However, because of the reduction in the cathode-heating coefficient with increasing current and electrode extension, reverse- and straight-polarity melting rates could be equal with long extensions or high currents.

Activation of the electrode surface produces a considerably stronger reduction of melting rate of the cathode electrode. Melting can be reduced to a rate less than that of the anode electrode at the same level of welding current. Both of the above equations show the resistance-heating factor to be less important under most conditions than anode or cathode heating. The equation can be used to determine the welding procedure that will produce desired changes in melting rate to satisfy a particular application. It is useful also to demonstrate the relative importance of the various factors affecting electrode consumption. It is important to remember that these equations are not necessarily valid with currents in excess of 500 amp and extensions of 2 in.; particularly with electrode diameters less than $\frac{1}{16}$ in. and are lengths less than $\frac{1}{4}$ in. Nevertheless, extrapolations beyond these limits are useful even though the results of calculations might not be exact.

The equations say nothing about the usefulness of a particular arc since the type of metal transfer, spatter, gauging of the plate, difficulty of igniting the arc, and other factors might prevent a particular technique such as the use of a long stick-out from being used to achieve a desired melting rate. The effects of the welding variables upon metal transfer and bead characteristics will be discussed in Part II of this report.

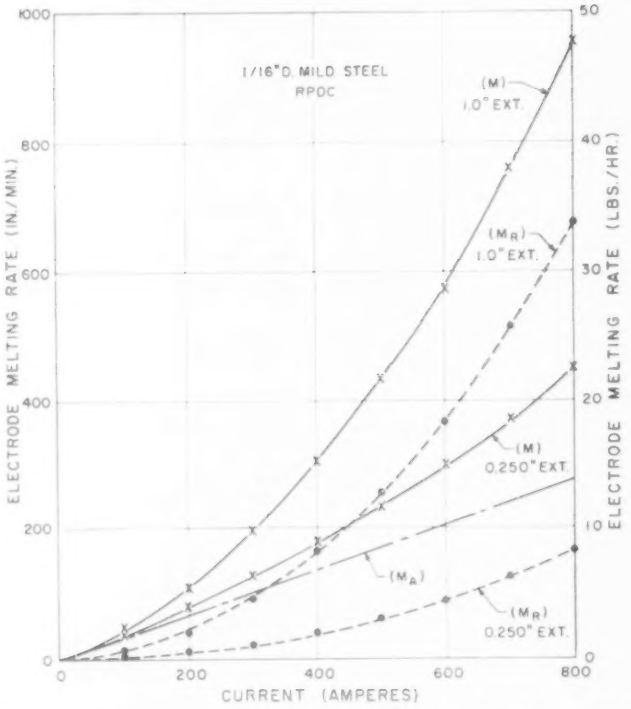

Fig. 15 Summation of anode (M_A) and electrical-resistance (M_R) heating with electrode extension of $\frac{1}{4}$ and 1 in. giving the real melting rate (M) for the same extensions of $\frac{1}{4}$ and 1 in. at various levels of welding current

Conclusions

1. The melting rates of electrodes having a fixed composition using the gas-shielded metal arc with reverse-polarity direct current are dependent only upon the welding current, electrode extension and electrode diameter.

2. The melting rates of gas-shielded metal-arc electrodes with straight-polarity direct current are dependent upon the same factors and, in addition, electrode activation and the composition of the shielding gases.

3. The heat for electrode melting is developed by anode or cathode reactions and electrical-resistance heating. Very little, if any, heat is due to radiation from the weld pool or the arc stream.

4. Anode heating is affected by the current and electrode diameter but not by the electrode extension.

5. Cathode heating is affected by the electrode extension, electrode activation and current.

6. The melting rate due to electrical-resistance heating is proportional to the electrode resistivity, extension and current squared, but inversely proportional to its cross-sectional area.

7. Electrode melting rates are generally independent of the shielding gas although the addition of small amounts of oxidizing gases to inert shields will cause a general decrease in the rate at straight polarity.

References

1. Wilson, J. L., Claussen, G. E., and Jackson, C. L. "The Effect of I²R Heating on Electrode Melting Rate." THE WELDING JOURNAL, 35 (1): Research Suppl. 1-s to 8-s (1956).
2. "New Welding Process Deposits Metal Faster." *Iron Age*, 90, 91 (June 16, 1955).
3. Cobine, J. D. "Gaseous Conductors." McGraw-Hill, New York (1941).
4. Loeb, L. B. "Fundamental Processes of Electrical Discharge in Gases." John Wiley, New York (1939).
5. Muller, A. and Greene, W. J. "Electric Arc and Resistance Welding." *AIEE*, 61 (1954).
6. Lesnewich, A. "Electrode Activation for Inert-Gas Metal-Arc Welding." THE WELDING JOURNAL, 34 (12): 1167-1178 (1955).
7. Rothschild, G. "Carbon Dioxide Shielded Consumable Electrode Arc Welding." *Ibid.*, 35 (1): 19-29 (1956).
8. Apps, R. L. and Milner, D. R. "Heat Flow in Argon-Arc Welding." *British Welding J.*, 35 (10): 475-485 (1955).
9. Nippes, E. F., Merrill, L. L., and Savage, W. F. "Cooling Rates in Arc Welds in ¼-in. Plate." THE WELDING JOURNAL, 28 (11): Research Suppl., 509-s to 616-s (1949).

THE CONTROL OF POROSITY IN HIGH-NICKEL-ALLOY WELDS

To insure freedom from weld porosity, nickel and its alloys require a reasonable amount of care with respect to arc length, adequacy of shielding and other welding variables and the added protection which a properly alloyed filler metal can provide

BY G. R. PEASE, R. E. BRIEN AND P. E. LEGRAND

ABSTRACT. Tests were conducted to establish what gases will cause porosity in nickel and high-nickel-alloy welds, and in what amounts they are damaging. Under conditions described in this study, nitrogen was found to be extremely damaging to the weld soundness of chromium-free alloys; oxygen, carbon monoxide and carbon dioxide were less so and hydrogen was relatively innocuous. Chromium-containing alloys were more resistant to damaging effects by all the gases.

The addition of titanium and other gas-fixing elements to the weld deposit increases the breadth of the welding conditions under which porosity-free welds can be prepared, but control of arc length and other welding variables is important, too.

Introduction

In general, molten metal is a good solvent for gas. Solidified metal is not. This broad relationship appears to hold for several of the more commonly encountered gases (the monatomic inert gases excepted) and for many of the metallic elements from which the important engineering alloys are made. If the assumption is made that porosity is the net result of this drop in solubility at the freezing point, and recognizing the very nature of the welding operation, it is not surprising that most metals and alloys are susceptible, in varying degrees, to weld-metal porosity.

If enlightened progress is to be made in the control of this troublesome defect, it becomes important to establish the identity of the offending gases and to examine each alloy or family of alloys for specific susceptibilities.

To a considerable degree this has been done. In the case of mild steel, for instance, it has been reported[1-4] that hydrogen, nitrogen and oxygen are all possible sources of porosity, the latter gas usually indirectly by reaction with carbon or hydrogen. Hydrogen is particularly troublesome in aluminum welds.[5-8] In the case of several other families of alloys, the literature includes references to the possibility of gas porosity, but the offending gases are not specifically identified. It is the intent of this paper, and the experimental work which it describes, to close this gap as it pertains to the high-nickel alloys, to the end that a better understanding will lead to greater assurance of high-quality weld deposits.

Scope

In the interest of holding the amount of experimental work to a reasonable minimum, the study was confined to three high-nickel alloys, which it was hoped would represent, in behavior, a major part of the large family of nickel-base alloys which industry is called upon to weld. Mild steel and Types 304, 310, 321 and 347 stainless steel were also included in the test program as reference materials. The high-nickel alloys included (a) a commercial grade of pure nickel, (b) a nickel-copper alloy known as Monel and (c) a nickel-chromium-iron alloy known as Inconel. The compositions are shown in Table 1. For each alloy, specific effects were established for each of the five gases, hydrogen, oxygen, nitrogen, carbon monoxide and carbon dioxide.

Experimental Procedure

For the most part, the method of establishing the influence of the several gases was based on an evaluation of weld beads made without filler metal, using the inert-gas-shielded tungsten-arc process. The shielding gas consisted of helium, to which measured amounts of the contaminating gas being studied were added. In the case of carbon dioxide, the corrosive effect on the tungsten electrode was so great, even at low concentration levels, that an alternate method of evaluation was required. Effects attributable to carbon dioxide were therefore measured using the inert-gas-shielded consumable-electrode process and matching filler wire. Because of the generally erratic behavior of the consumable-electrode arc under helium, argon was substituted for helium as the inert supporting gas in this series of tests.

Helium was selected over argon as the supporting gas for the tungsten-arc series of welds on the basis of its preferred use in this country for the welding of nickel-base alloys when welded by this method. It is possible that, with argon instead of helium, certain of the test results, particularly the threshold levels at which porosity was first detected, would have been displaced in one

Table 1—Composition of High-Nickel Alloys

	C	Si	Mn	Fe	Cu	Cr	Ni	S
3- x 6- x $\frac{1}{8}$-in. sheet								
Commercially pure nickel	0.06	0.02	0.22	0.11	0.04		Bal	0.005
Monel	0.10	0.16	0.96	1.54	30.18		Bal	0.005
Inconel	0.04	0.23	0.23	6.35		14.62	Bal	0.007
4- x 6- x $\frac{3}{8}$-in. plate								
Commercially pure nickel	0.05	0.02	0.30	0.10	0.07		Bal	0.005
Monel	0.18	0.22	0.93	1.33	32.24		Bal	0.013
Inconel	0.03	0.15	0.15	6.36	0.11	14.33	Bal	0.007

The authors are associated with the Research Laboratory of the International Nickel Co., Inc., Bayonne, N. J.

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direction or the other. It is doubtful, however, that the qualitative relationships would have been significantly different.

With the exception of hydrogen, which was evaluated on a somewhat different basis than the other gases, the diluent gas was fed into the main stream of helium at predetermined rates which were designed to provide concentrations at the nozzle of the torch covering the range 0.0 to 10% by volume. Hydrogen was fed directly into the annular orifice of a specially constructed welding torch which was designed to use hydrogen as a shrouding gas.[7] The rate of flow of both the contaminating and supporting gases was measured with pre-calibrated flowmeters, and the concentration levels at the torch calculated from the relative flow rates. To make it possible to explore the very low end of the concentration range, it was necessary to pre-mix the contaminating gas with helium in known ratios and use the helium-contaminating gas mixture, usually in a 90-10 ratio, as the feed-in gas. The pre-mixed gases were obtained locally in especially prepared 220-cu ft compressed-gas cylinders. The combined gas flow was at the rate of 30 cfh with the other welding conditions standardized as shown in Table 2.

Table 2—Test Conditions for Welds Made with N_2, O_2 and CO

Current	150 amp, d-c, straight polarity
Arc length	0.050 in.
Travel speed	16 in./min
Electrode	1/8-in. diam thoriated tungsten

The electrode holder, or torch, was mounted on a motor-driven travel carriage and used to prepare a series of beads, such as the one shown in Fig. 1, for each gas and each alloy, the variable being the concentration of the contaminating gas. The sheet specimens, upon which the tests were run, consisted in each case of 3- x 6- x 1/8-in. coupons from regular commercial heats of material. Complete penetration was avoided in order to eliminate the possibility of atmospheric contamination of the molten pool through the root surface.

The evaluation, or determination of the porosity level, was made by dressing the completed test welds with a 200-grit abrasive wheel sufficiently to expose subsurface porosity, and then examining the polished and etched surfaces, at ×15, under a stereoscopic binocular microscope. Each bead was rated with respect to the severity of porosity by comparing it with a set of "porosity standards" which had been previously prepared and graded on the basis of the number of gas holes per linear inch of weld bead.

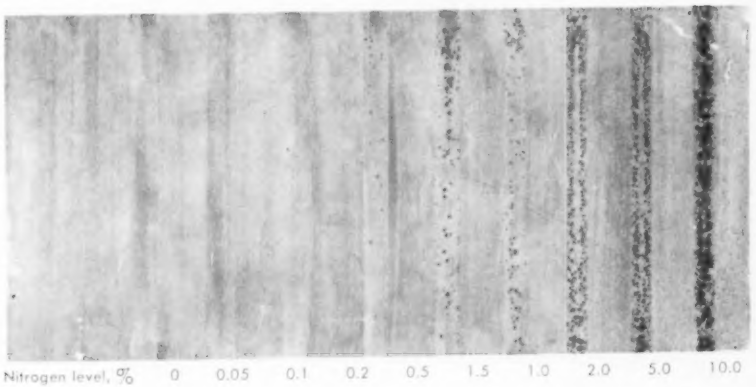

Fig. 1 Typical weld-bead test plate. Weld beads made on commercially pure nickel sheet using helium atmosphere contaminated with increasing amounts of nitrogen. Three-fourths actual size

For the carbon-dioxide series of tests which were made using the consumable-electrode process, the experimental conditions shown in Table 3 applied.

Table 3—Test Conditions for Welds Made with CO_2

Plate dimensions	4 x 6 x 3/8 in.
Current	260-310 amp, dc, reversed polarity
Wire diameter	0.062 in.
Wire feed	130-285 in./min
Gas flow	50 cfh

Test Results

Under the experimental conditions described above, the influence of the various contaminating gases may be summarized as follows.

Effect of Nitrogen

Of the several gases studied, nitrogen was found to be, by far, the most potently damaging to the soundness of high-nickel-alloy weld deposits (Fig. 2). Under the conditions of test, as little as 0.1-0.2% was enough to induce the first traces of porosity in Monel and nickel (Figs. 3-4). At 1%, the porosity level was intolerably severe. The stainless steels which, incidentally, are not represented separately since they all responded similarly, were unaffected by as much as 10% of nitrogen. Inconel responded similarly to the stainless steels.

The concentration level at which nitrogen was found to be damaging to the soundness of the control welds in mild steel was somewhat higher than the 1% level which Ludwig[5] found to be the threshold in an earlier series of test welds made by the argon-shielded con-

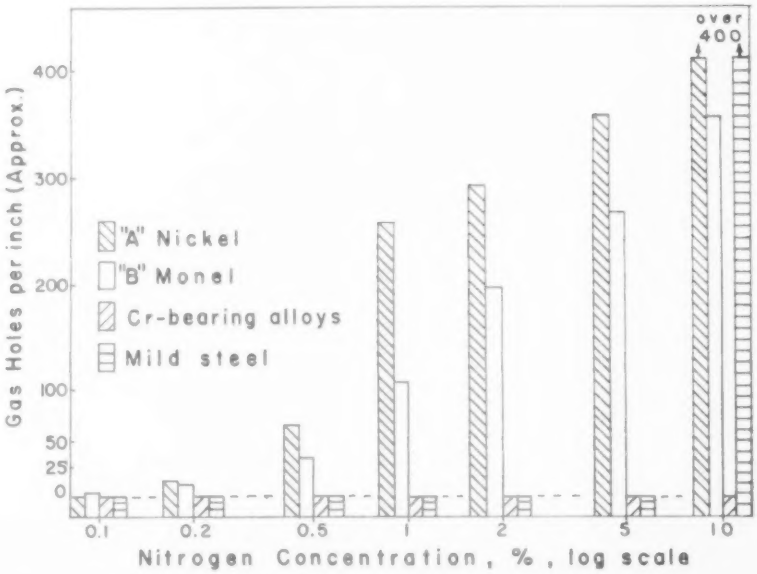

Fig. 2 Effect of nitrogen concentration upon porosity

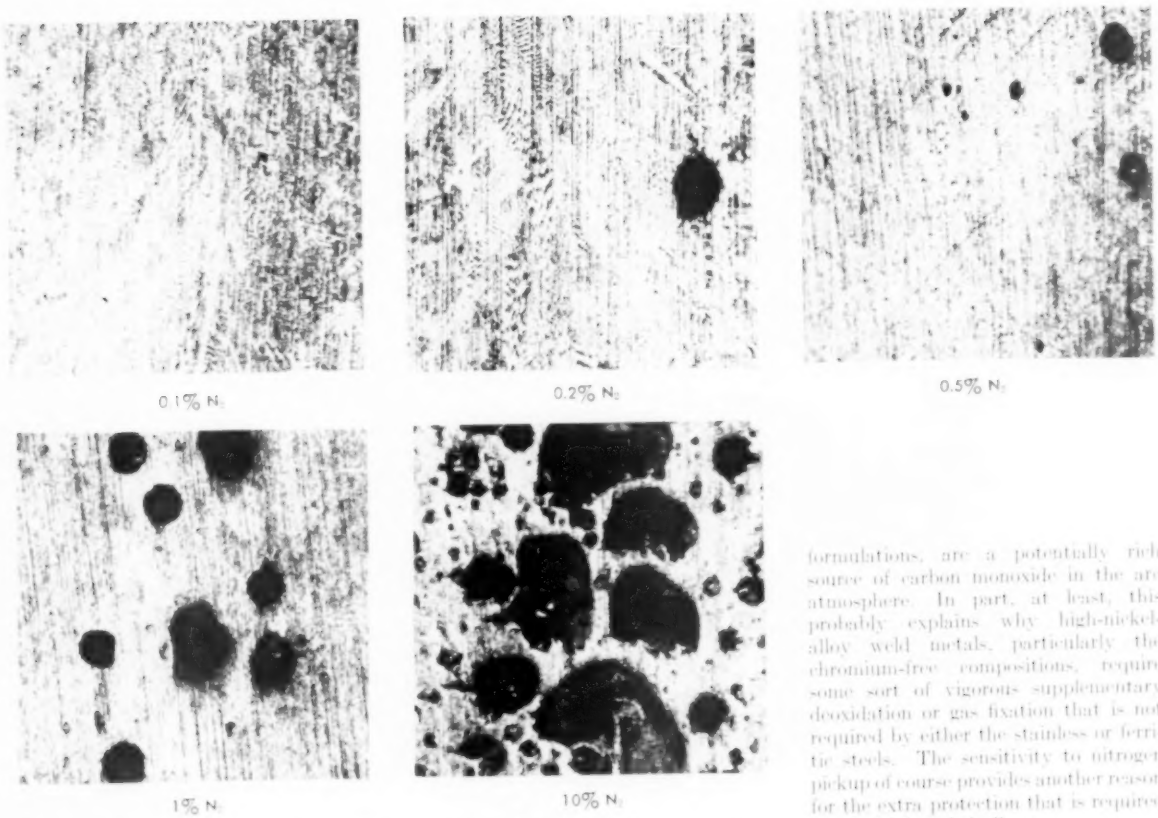

Fig. 3 Porosity in weld beads deposited on commercially pure nickel using helium atmosphere contaminated with various amounts of nitrogen. X15

sumable-electrode process. Whether this difference is traceable to minor differences in the composition of the steels, the welding method or the fact that argon was used as the supporting gas instead of helium, is not known; nor is it of great practical importance. Whether the threshold level is 1% or something between 5 and 10%, it is clear that extraneous sources of nitrogen must be avoided to insure porosity-free welding of ferritic materials. It is additionally clear that chromium-free nickel-alloy arc welds are more sensitive to the presence of nitrogen than are mild-steel welds by a factor of at least ten.

Although the present investigation does not offer experimental proof, porosity effects attributable to nitrogen can be expected to be limited to welds made by electric-arc methods only. Ames and Kahn[9] point out that nitrogen, to be soluble and absorbed into the melt, must be present in the dissociated or monatomic form. In view of the fact that a high-energy arc can effect the necessary dissociation, it was not surprising that nickel-copper castings were found to be particularly subject to nitrogen porosity when melted in an indirect-arc furnace, they concluded.

Similarly, in welding, the dissociating action of the arc[10] is available to render nitrogen soluble in the melt from whence it is rejectable, as porosity, during freezing. Reasoning of this sort seems to explain the fact that welds made in nickel and Monel by the oxyacetylene process require smaller corrective additions than welds made by any of the several arc-welding processes.

Effect of Carbon Monoxide

Second only to nitrogen as a potential source of unsoundness in high-nickel alloys, in these tests, was carbon monoxide. The threshold for incipient porosity appears to be about 4-5% (Fig. 5), with very severe damage encountered at 7-10%. As in the case of nitrogen, only the chromium-free high-nickel alloys were affected and, again, mild steel was shown to be less sensitive than nickel-base alloys.

If a practical significance is to be attached to the observation that carbon monoxide is potentially troublesome, it is not likely to be found in the realm of inert-gas welding. It can be an important consideration in metal-arc welding with flux-covered electrodes, however. Alkaline earth carbonates, which form a part of most present-day coating formulations, are a potentially rich source of carbon monoxide in the arc atmosphere. In part, at least, this probably explains why high-nickel-alloy weld metals, particularly the chromium-free compositions, require some sort of vigorous supplementary deoxidation or gas fixation that is not required by either the stainless or ferritic steels. The sensitivity to nitrogen pickup of course provides another reason for the extra protection that is required by the high-nickel alloys.

Effect of Oxygen

Oxygen appears to be almost but not quite as damaging as carbon monoxide (Fig. 6). Slight porosity was encountered in the Monel and nickel welds at the same 4-5% level but, at the 10% level, the porosity count was a little less than it was with carbon monoxide. Chromium-bearing welds again were free from porosity in atmospheres containing up to 10% of the contaminating gas, but the control welds in mild steel were unmistakably more sensitive to oxygen than to carbon monoxide.

Under circumstances where entrained air might be responsible for the presence of oxygen in an arc atmosphere, nitrogen would, of course, also be present. A comparison of the data of Figs. 2 and 6 suggests that, as far as contamination of the arc atmosphere with air is concerned, nitrogen is a far greater problem than oxygen. This conclusion with respect to the relative potency of the two gases is in disagreement with conclusions reached by Milner[11] in some recent work done in England. It is possible, however, that the results would have been in closer agreement if Milner's investigation had included additional tests at intermediate nitrogen levels.

The observation that oxygen additions up to 5% have little or no adverse effect on weld soundness might lead one to the conclusion that the use of the

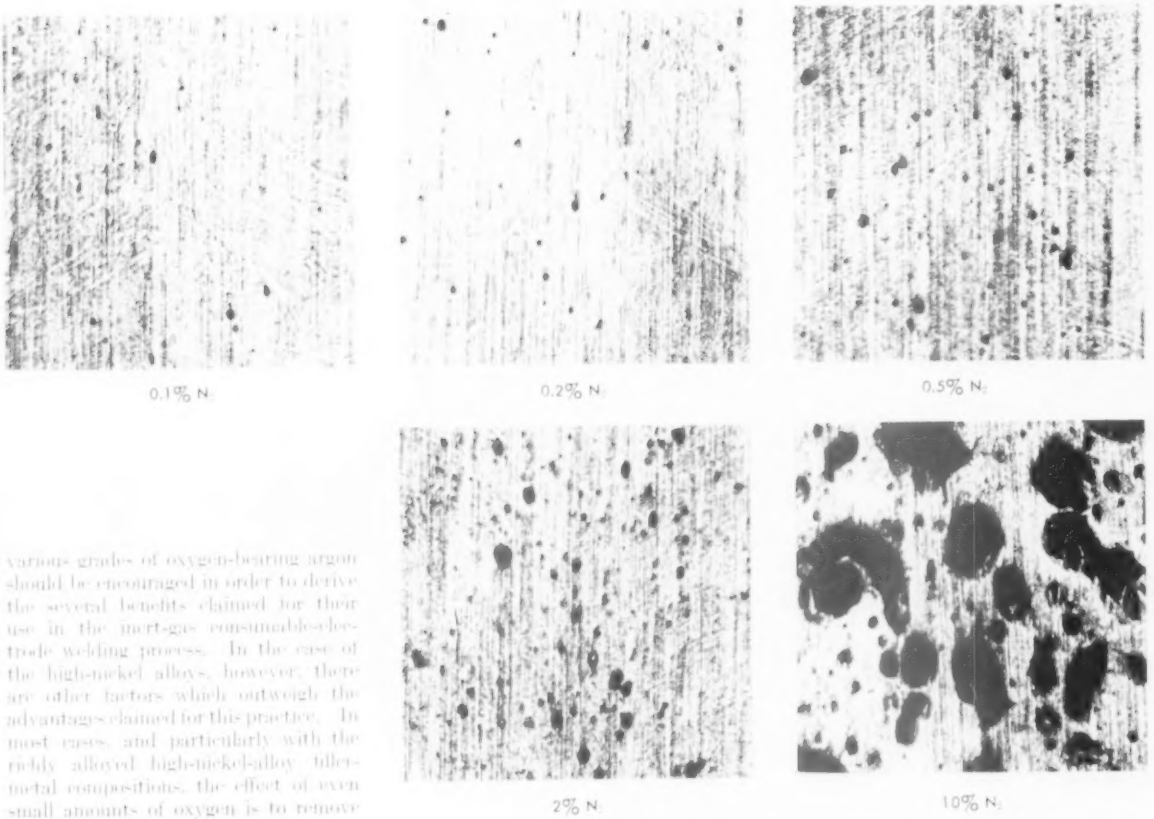

Fig. 4 Porosity in weld beads deposited on Monel using helium atmosphere contaminated with various amounts of nitrogen. X15

various grades of oxygen-bearing argon should be encouraged in order to derive the several benefits claimed for their use in the inert-gas consumable-electrode welding process. In the case of the high-nickel alloys, however, there are other factors which outweigh the advantages claimed for this practice. In most cases, and particularly with the richly alloyed high-nickel-alloy filler-metal compositions, the effect of even small amounts of oxygen is to remove from the molten weld metal, by oxidation, some of the critically important elements which contribute to the satisfactory welding performance and properties of this family of alloys. In addition, the refractory oxide films, or crusts, which form on the weld surfaces as a result of these oxidation reactions, can seriously interfere with the production of satisfactory multiple-pass welds. Figure 7 demonstrates the extent to which this type of surface oxidation can occur in the case of a Monel weld bead deposited by the consumable-electrode process under argon containing 5% oxygen.

Effect of Hydrogen

As mentioned before, the effects of hydrogen were studied under somewhat different conditions than the other gases and, in fact, at a much earlier date. As early as 1950 it was shown by one of the present authors and also in other laboratories[5, 12, 13] that, by supplementing the inert-gas shield with hydrogen, the soundness of welds in nickel-base alloys could be considerably enhanced. It was pointless, therefore, to include hydrogen in the present series of tests, the primary object of which was to seek out possible subversive effects.

In the previous work, hydrogen was beneficial only under adverse welding conditions. Among the adverse conditions that were likely to be encountered at that time, was the use of inert gas of substantially lesser purity than that now available. Impurity contents as high as 1.5% were not uncommon, for instance. Under these circumstances, and particularly when welding was done at slow travel speeds, a beneficial effect could be demonstrated for hydrogen additions (Fig. 8), with the optimum level consistently falling in the range 10 to 25%. Greater amounts were sometimes damaging and sometimes not. In one series of tests, considerable porosity was experienced in Monel at the 50% level and in others the beneficial effect persisted at this level.

Using present-day gases with purity levels in excess of 99.9%, and especially under optimum welding conditions, there seems to be little or no justification for recourse to hydrogen additions, from the standpoint of insuring porosity-free weld deposits. On the other hand, McElrath and Gorman[14] have shown that, in tungsten-arc welding at least, hydrogen additions to argon have the effect of increasing the arc-voltage and by so doing usefully increase the depth of penetration and/or the speed of welding. Significantly, and confirming the earlier work, there was no adverse effect from the presence of hydrogen, *per se*, on the soundness of any of their high-nickel-alloy welds. Under some conditions, elongated voids were observed but these were attributed solely to the mechanical entrapment of condensed water vapor.

Effect of Carbon Dioxide

Although its extremely corrosive effect on the electrode has ruled out the use of carbon dioxide as a substitute for helium or argon in tungsten-arc welding, it has received considerable attention recently as a less-expensive shielding gas for inert-gas consumable-electrode welding. Its practicability has been demonstrated for the welding of mild steel, but stainless-steel welds have been shown to be less satisfactory with carbon-dioxide shielding than with argon shielding.[15] For the high-nickel alloys, too, the objectional features of the use of carbon dioxide are of a sufficient magnitude to discourage its use. The adverse effects are four-fold: (1) the creation of spatter which is much coarser and more abundant than with other metals, (2) the loss of important deoxidizers and malleableizing additions, (3) in the case of unmodified nickel or Monel, the generation of gas porosity

Table IV—Recovery of Oxidizable Elements in CO_2-Shielded Weld Deposits

	C	Mn	Si	Cr	Al	Ti	Mg	Cb*	Ta*
				Nickel					
Filler wire	0.04	0.29	0.44		0.64	3.17	0.030		
Weld deposit	0.05	0.26	0.43		0.19	1.44	<0.01		
				Monel					
Filler wire	0.03	0.33	0.98		0.41	2.24	0.025		
Weld deposit	0.04	0.14	0.76		0.12	0.72	<0.01		
				Inconel					
Filler wire	0.04	0.25	0.24	15.95			0.025	1.12	0.47
Weld deposit	0.06	0.13	0.19	14.32			<0.01	0.59	0.17

* Filler wire made with ferro-columbium-tantalum alloy containing columbium and tantalum in a 2 to 1 ratio.

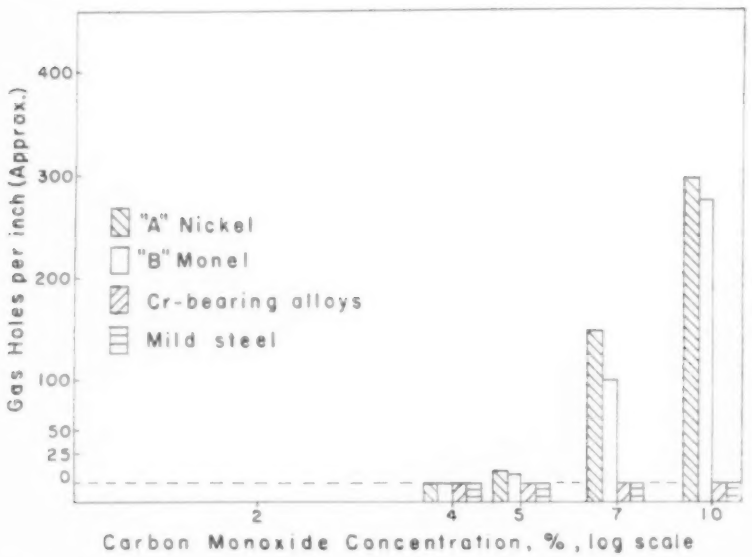

Fig. 5 Effect of carbon-monoxide concentration upon porosity

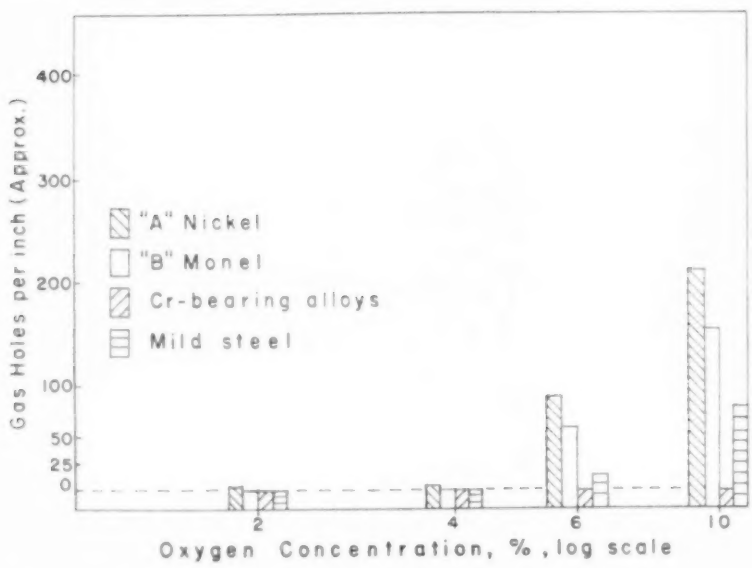

Fig. 6 Effect of oxygen concentration upon porosity

and (4) in the case of compositions containing large amounts of chromium, titanium or aluminum, a heavy residue of oxides on the weld surface which would be troublesome in multiple-pass welds. The appearance of single-pass deposits made with 100% carbon dioxide and a 50% carbon dioxide-50% argon mixture using both unmodified and titanium-bearing nickel filler wires is shown in Fig. 9. Corresponding deposits made in Monel and Inconel were similar in appearance except that no porosity was encountered in any of the Inconel deposits. In no instance was a deposit obtained where both appearance and soundness could be considered acceptable for high-quality fabrication.

The best of the group, but still of questionable quality, was the Inconel deposit made with columbium-modified filler wire. The weld surface was heavily oxidized (Fig. 10) and some subsurface cracking was evident, but the spatter was at a minimum and there was no porosity. In this case (Table 4), as in all others, there were very substantial losses of some of the elements which are important to the welding behavior and properties of high-nickel-alloy welds. These elements are largely recoverable when using argon, but with carbon dioxide the losses are very high.

Pure argon — Argon plus 5% oxygen

Fig. 7 Surface oxidation on Monel weld bead deposited by the consumable-electrode process under argon containing 5% oxygen. Two-thirds actual size

Control Through Welding Variables

Once the porosity-inducing gases have been identified, it then becomes important to know what measures are necessary to insure freedom from their subversive action. In the case of the high-nickel alloys, two approaches are possible and both are utilized commercially. One approach depends upon the adjustment and control of welding variables such that the porosity-inducing gases are excluded from the arc atmosphere as completely as is possible, consistent with the limitations of the welding method being employed. The other approach involves adjustment of the weld-metal composition through the addition of appropriate deoxidizers and gas-fixing elements. In many cases, of course, the two methods of control are supplementary.

Only in machine welding, using the tungsten-arc process, is it possible to provide the sort of control which is necessary to insure porosity-free welds in wrought nickel, Monel and other chromium-free high-nickel alloys without recourse to the use of porosity-correcting additions.

By its very nature, the arc atmosphere produced with covered electrodes can be expected to contain at least one of the subversive gases in substantial quantities. In this process, therefore, control of porosity must be primarily through composition. In manual tungsten-arc welding and in inert-gas consumable-electrode welding, whether manually or machine operated, compositional adjustment is also usually necessary. The beneficial effects derived from contained chromium lessen considerably the need for the supplementary elements in the case of Inconel and related alloys.

In all of the welding methods, the use of a short arc is one of the most important of the several welding variables, with respect to its influence on weld quality. In the tungsten-arc welding of Monel or nickel, for instance, the arc length must be limited to about 0.050 in. to avoid porosity (Fig. 11). This requirement alone is sufficient to limit the welding of these metals without added filler wire to the mechanized tungsten-electrode process.

Without compositional adjustment, such as that provided by the addition of filler wire, it is particularly essential to insure that the molten weld metal is amply covered with inert gas. The flow of gas required to do this will of course depend upon the welding speed, the torch configuration, fixturing and joint design and other related factors. The basic consideration is that the coverage be complete enough to exclude the ambient atmosphere until the metal has had time to freeze. Protection from drafts of moving air is particularly important.

Backing gas or flux is frequently used, but more often to control the root contour than to control porosity. If flux is used for this purpose, it must be allowed to dry lest the retained moisture become a source of porosity.

This susceptibility to moisture suggests that water vapor should perhaps be added to the list of subversive gases. However, the effect of moisture, whenever it has been encountered, (Fig. 12) appears to have been the result of mechanical entrapment, as described by McElrath and Gorman,[14] rather than the result of solution in or reaction with the molten metal. More information is needed with respect to the effects of water vapor, *per se*, before its tolerable limits as a gaseous contaminator can be established.

Control Through Composition

Because of the several factors mentioned in the previous paragraphs, hazards are ever present of inadvertent or unavoidable contamination of the arc atmosphere with one or more of the subversive gases. There are, therefore, relatively few situations in the welding of the high-nickel alloys, particularly the chromium-free varieties, where additions of gas-fixing elements to the fusion are not required. Of the several elements which are commonly used for this purpose, titanium is particularly well

Fig. 8 Beneficial effect of hydrogen upon porosity in tungsten-arc welds in commercially pure nickel. Welds made at 8 ipm using low-purity argon

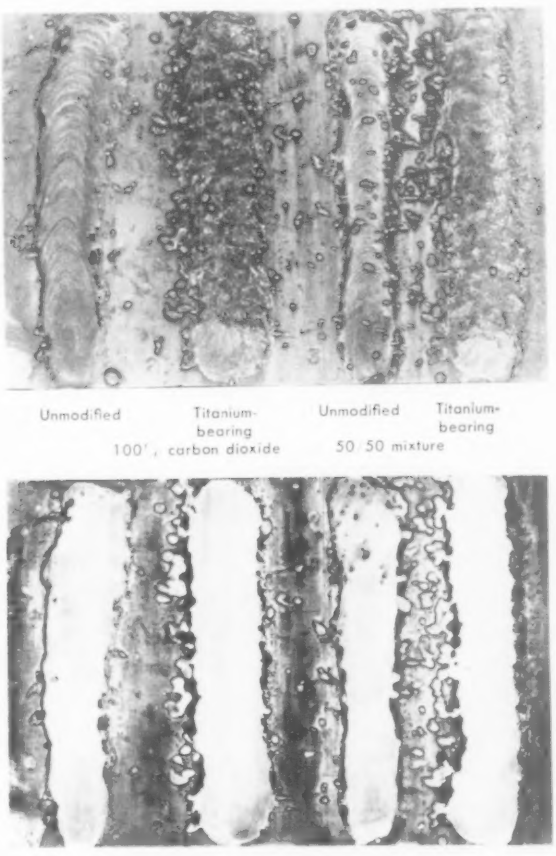

Fig. 9 Appearance of single-pass deposits made by the consumable-electrode process with 100% carbon dioxide and with a 50% carbon dioxide-50% argon mixture using both unmodified and titanium-nickel filler wires. Five-eighths actual size

suited for use in the high-nickel alloys because it forms stable compounds with each of the elements nitrogen, carbon and oxygen which are responsible, collectively, for initiating porosity in this family of alloys. Manganese, silicon and aluminum are also used to supplement titanium in its corrective action.

Reference to published filler-metal specifications for the high-nickel alloys[16, 17] shows that the need for these gas-fixing additions has been recognized and provision made for their incorporation into the weld deposit in appropriate amounts. The amount and types of additions which are made vary with the welding method to be used and the alloy involved. Whatever the method or alloy, however, if a filler wire is called for, it is important that its composition conform to these established requirements. For the most part, no interchange is possible. Porosity can be expected, for instance, if the wire compositions which are intended for use with the oxyacetylene process are used for inert-gas welding. Conversely, the wires which are intended for use in inert-gas welding will be found to be sluggish and difficult to handle under the oxyacetylene flame. Likewise, with few exceptions, the wire obtained by stripping a covered electrode is not satisfactory for either of the two gas-welding methods.

Discussion

With nitrogen playing the important part that it does in subverting the soundness of high-nickel-alloy weld metal, and with oxygen also being damaging, it is obvious that any effort spent in attempting to exclude the ambient atmosphere from the welding arc is an effort well spent. Diligence in this direction can be relaxed, somewhat, whenever it is possible to take advantage of the fortifying action of a properly adjusted filler wire but, even under these circumstances, air can be a source of porosity unless care is exercised to keep the level of contamination to a minimum. There never has been any need, for instance, for specifying that nickel or its alloys be welded in a "dry box" or an inert-atmosphere filled chamber, but on the other hand porosity can be expected if an attempt is made to complete an inert-gas-shielded weld in the presence of drafts of moving air. To insure freedom from weld porosity, nickel and its alloys require no more than a reasonable amount of care with respect to arc length, adequacy of shielding and other welding variables and the added protection which a properly alloyed filler wire or covered electrode can provide.

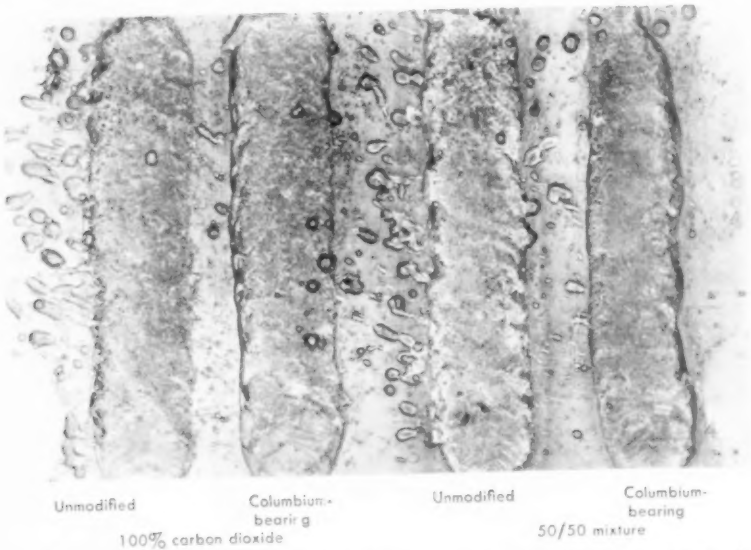

Fig. 10 Oxidation and spatter on surface of single-pass deposits made by the consumable-electrode process with 100% carbon dioxide and with a 50% carbon dioxide-50% argon gas mixture using both unmodified and columbium-bearing Inconel filler wires. Seven-tenths actual size

Fig. 11 Effect of arc length on soundness of autogenous tungsten-arc welds in one-eighth-inch thick Monel sheet. Five-ninths actual size

Fig. 12 Porosity produced in a tungsten-arc weld by mechanical entrapment of water vapor. Three-fourths actual size

Acknowledgment

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References

1. Muir, A. R. "A Review of Literature on the Causes of Porosity in Steel Welds." *Brit. Welding J.*, 3 (3): 98–102 (1956).
2. Warren, D. and Stout, R. D. "Porosity in Mild Steel Weld Metal." The Welding Journal, 31 (9): Research Suppl., 406s to 420s (1952).
3. Dyer, Glenn W. and Stout, R. D. "Porosity in the Welding of Carbon Steel." *Ibid.*, 32 (9): Research Suppl., 454s to 460s (1953).
4. Ludwig, H. C. "Nitrogen Effects in Argon Arc Welding Atmospheres." *Ibid.*, 34 (9): 409s to 414s (1955).
5. Pumphrey, W. I. and West, E. G. "The Metallurgy of Welding Aluminum and Its Alloys." *Brit. Welding J.*, 4 (7): 297–306 (1957).
6. Cresswell, R. A. "The Effect of Impurities in Argon on Inert-Gas Shielded-Arc Welds." *Brit. Welding J.*, 4 (4): 181–188 (1957).
7. Rank, M. P., Crumbley, C. F., and Lee-Gayer, E. F., U. S. Patent 2,680,800.
8. Ludwig, H. C. "Nitrogen Effects in Argon Arc Welding Atmospheres." The Welding Journal, 34 (9): Research Suppl., 409s to 414s (1955).
9. Anyos, B. N. and Kahle, N. A. "Gas Absorption Phenomena and Deoxidation of Cast Monel." *Trans. of the Am. Foundrymen's Assoc.*, 55, 558–573 (1947).
10. Fast, J. D. "The Dissociation of Nitrogen in the Welding Arc." *Philips Res. Rept.*, 2, 382–398 (1947).
11. Milner, D. R. "Porosity in Nickel Welded by the Argon-Arc Process." *Brit. Welding J.*, 3, 542–5 (1956).
12. Noland, R. A. and Szymko, C. F., U. S. Patent 2,602,871.
13. Zeno, R. S. and Leslie, H. L. C. "The Inert-Arc Welding of Thin-Walled Tubing." The Welding Journal, 30 (11): 986–992 (1951).
14. McElrath, T. and Gorman, E. F. "Argon-Hydrogen Shielding Gas Mixtures for Tungsten-Arc Welding." *Ibid.*, 36 (1): 28–35 (1957).
15. Rothschild, G. B. "Carbon Dioxide-Shielded Consumable-Electrode Arc Welding." *Ibid.*, 35 (1): 19–29 (1956).
16. Tentative Specifications for Nickel and Nickel-Base Alloy Bare Welding Filler Metals. ASTM Designation B 304-56 T; AWS Designation A 5.14-56 T.
17. Tentative Specifications for Nickel and Nickel-Base Alloy Covered Welding Electrodes. ASTM Designation B 295-54 T; AWS Designation A 5.11-54 T.

THE EFFECT OF WELDING SPEED ON STRENGTH OF 6061-T4 ALUMINUM JOINTS

Report gives the results of an investigation to determine the relationship between strength after aging to welding speed or heat input

BY WILLIAM L. BURCH

SUMMARY. The factors affecting tensile strength of welded-and-aged 6061-T4 aluminum joints were studied. It was found practicable to weld, by the inert-gas-shielded tungsten-arc process, joints which upon aging had nearly the strength of 6061-T6. On large airborne tanks this technique was valuable because it avoided solution heat treatment of the finished structure and attendant quenching and distortion problems. Welds were single pass in $^3/_{16}$-, $^1/_4$- and $^1/_2$-in. thickness.

Welding heat was most harmful at an overaged zone in the base metal $^1/_4$ in. from the weld; tensile failure usually was here. The overaged zone reached a peak temperature of about 700° F regardless of welding speed. The intensity of overaging depended upon the time this zone was in the 570-700° F range. This time was inversely proportional to the welding speed.

Of the many factors studied, welding speed was the most important one affecting response to aging. Slow speeds caused high heat input, practically annealing the base metal. With increasing speeds the joint strength increased rapidly up to a speed of 15 ipm, above which the tensile strength was uniformly high at 90-95% of -T6 strength.

Introduction

Type 6061 has the highest strength of the heat-treatable aluminum alloys commonly being welded in the aircraft industry. The usual fabrication sequence is to weld the annealed material, then solution heat treat and age it. This works well for small assemblies, giving maximum joint strength. Solution heat treatment, however, is not practical for large structures because of the difficulties encountered in obtaining furnace equipment, in quenching and in preventing distortion.

When it was proposed to build large airborne propellant tanks of 6061 alloy, it became necessary to investigate fabrication sequences which would give high joint strength without resorting to any heat treatment of the finished tank other than artificial aging. It was known that 6061 in the solution heat-treated condition (6061-T4) if welded rapidly enough, would retain most of its ability to respond to aging and thereby develop nearly the strength of fully heat-treated material (i.e., 6061-T6). Conversely, if welded slowly, it became annealed and would not respond to aging.

This report gives the results of the investigation to determine the relationship between strength (after aging) to welding speed or heat input. Based on these results, tanks were made of 6061-T4 material, taking advantage of the easy formability in that condition, and then the completed tanks were aged to 6061-T6. There was no distortion from aging, and joint strengths of around 40,000 psi were achieved. This was about 90% of the 45,000 psi typical for 6061-T6. Two welded joints from a tank are shown in Fig 1.

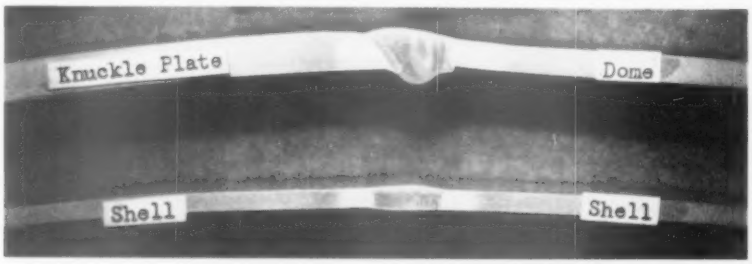

Fig. 1 Production welds in 6061-T4, welded and aged. Thicknesses: $^1/_4$ to $^3/_{16}$ in. and $^1/_2$ to $^1/_4$ in.

Apparatus and Materials

All welding was done with the inert-gas-shielded tungsten-arc equipment shown in Fig. 2. The welding head and wire feeder were mounted on a carriage and speeds between 4 and 50 ipm were investigated. Power was supplied by an a-c transformer in which the current wave is balanced by capacitors. Dynamometer-type meters were used for measuring arc voltage, welding current and wattage. These respond properly to the unbalanced and distorted wave shapes likely to be met in a-c welding.[1] The shielding gas was standard argon except for the two sets of runs using helium. Pure-tungsten electrodes were used.

Fig. 2 Laboratory welding equipment, automatic inert-gas-shielded tungsten-arc process

The jig had water-cooled copper holddowns and a mild-steel backing with a groove 0.040 deep by $^3/_{16}$ in. wide under the weld joint. Clamping was by an air-inflated firehose beneath

William L. Burch is associated with The Bell Aircraft Corp., General Engineering Laboratories, Buffalo, N. Y.

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the backing. For some studies where it was desirable to intensify and widen the heat-affected zones, the plates were thermally insulated from the jig by long strips of $\frac{1}{16}$- x 1-in. asbestos tape. These are visible at the end of the jig, Fig. 2.

The test material was 6061 aluminum alloy heat treated to -T4 by the investigators and chemically cleaned before use. The filler wire was the commonly used 5% silicon-aluminum alloy, Type 4043. All welds were single pass in square-groove butt joints between two 4- by 12-in. plates, usually of $\frac{1}{4}$-in. gage. Some were made on $\frac{1}{16}$- and $\frac{1}{8}$-in. gage.

Tensile and Yield Strength Determinations

Only ultimate tensile strength and elongation are reported for the welded joints. Yield strength was deleted to prevent misinterpretation of the values inasmuch as the actual yield strength of the soft zones is lower than the yield strength as determined across the 2-in. gage length. (Also the actual elongation of the soft zone will be higher than the apparent value.) The errors arise because most of the deformation occurs in the two $\frac{1}{8}$-in. wide soft zones and these are stretched far past their yield strength before a yield strength is recorded for the 2-in. gage length.

Tensile specimens had a reduced section $\frac{1}{2}$ in. wide by $2\frac{1}{2}$ in. long and the weld reinforcement amounting to 20 to 40% was left on. All reported results are an average of three or more tests.

Hardness Surveys

Hardness surveys taken across the weld and heat-affected zones were valuable in studying such zones and in explaining welding heat effects to others. The relation between hardness and tensile strength, Fig. 3, enabled strength to be predicted within 2000 psi. This was especially useful in field testing of tanks using portable Rockwell and Barcol Impressor testers. The surveys were made with the Rockwell F scale ($\frac{1}{16}$-in. ball and 60-kg load). Each impression disturbed a $\frac{1}{16}$-in. circle of metal, but by staggering the impressions, readings could be taken for every $\frac{1}{32}$-in. increment of distance.

Metallurgical Investigation

Statement of the Problem

In making a weld, the heat of the arc moving along the joint melts a path in the base metal. The heat from the weld flows to the surrounding base metal and causes complex thermal cycles which differ depending upon the distance from the weld. At the edge of the weld there will be a rapid heating and cooling rate and a peak temperature equal to the melting point (1150° F). Further away from the weld the peak temperature will be lower and the heating and cooling rates will be less severe.

The problem in this weld-and-age sequence is to determine how 6061-T4, which is in a very heat-sensitive condition, can be subjected during welding to this variety of heating cycles without appreciably changing its response to the subsequent hardening step known as aging. The answer, oversimplified, is that, if the time at temperature is kept short enough, the expected heat effects (overaging) will not occur.

A brief review of the heat treatment of 6061 alloy may be advisable. This is an Al-Mg-Si alloy which is hardenable by a precipitation heat treatment. Heat treatment is in two steps; the first, called solution heat treatment, consists of heating to 970° F to dissolve the magnesium silicide and then quenching rapidly. This produces the 6061-T4 condition. The quench is fast enough that there is not time for the magnesium silicide to precipitate out in accordance with its decreasing solubility at lower temperatures. The second step of the heat treatment, called aging, consists

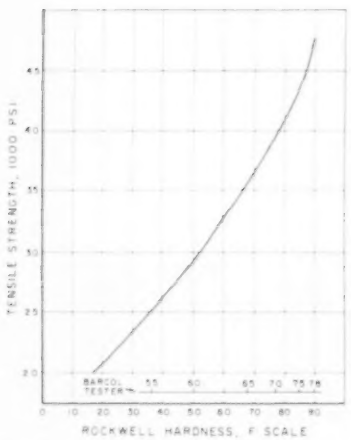

Fig. 3 Relation of tensile strength to hardness (of softest zone) for estimating joint strength, 6061 aluminum alloy

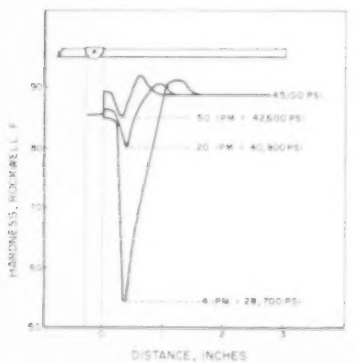

Fig. 4 Effect of three widely different welding speeds on hardness of 6061–T4, welded on insulated jig, then aged

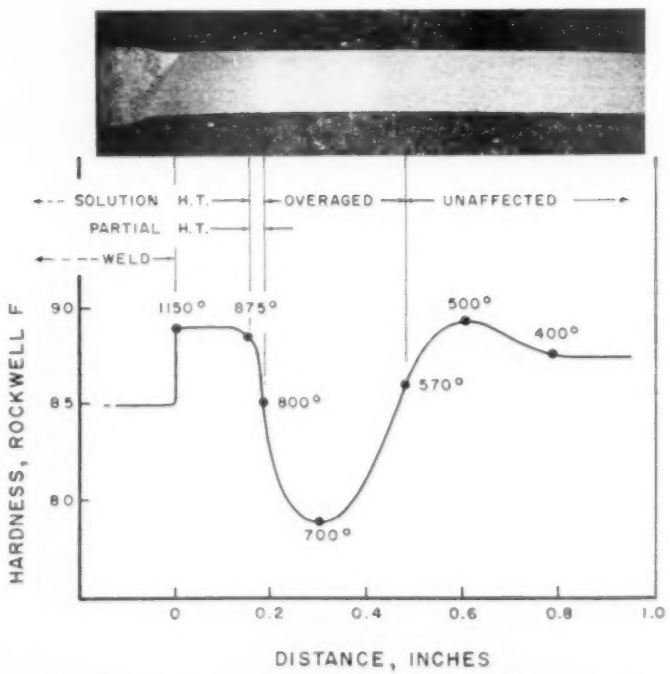

Fig. 5 The heat-affected zones and hardness survey thereof, with significant peak temperatures noted; $\frac{1}{4}$-in. 6061-T4 welded at 25 ipm, aged

of heating the -T4 at 350° F for 8 hr. This gives the strong (45,000 psi) 6061-T6 condition. The strengthening results from the precipitation of submicroscopic particles of the magnesium silicide phase. Alloys heated to higher temperatures or for longer times than required to develop maximum hardness are said to be "overaged." Heating even higher, around 775° F, produces annealing whereupon there is practically complete precipitation of the magnesium silicide in a relatively coarse form. Aging, overaging and annealing represent different degrees of the same precipitation reaction.

The Heat-Affected Zones

The principal heat effect is overaging and the intensity of this depends upon the welding speed. This is shown by the hardness surveys in Fig. 4 of three joints welded at widely different speeds. With increasing speed the soft zone becomes shallower, narrower and moves closer to the weld. (These are ½-in. 6061-T4 welded on insulated jig, then aged.) Actual tensile strength of joints and base metal is indicated.

Regardless of speed, the same zones exist so the discussion of those in a typical weld applies also to welds made at other speeds. Figure 5 shows half of the joint and a hardness survey across it after aging. (This is ½-in. 6061-T4 welded at 25 ipm in an insulated jig.) The peak temperatures reached by the base metal also are noted at significant points on the survey. The variation in hardness (strength) across the joint is explained as follows:

The weld metal is principally 6061 alloy and is heat treatable. It and the first 0.15 in. of base metal have been heated above 875° F and have cooled rapidly enough that they are in the solution heat-treated (-T4) condition. Upon aging, they reach approximately full-T6 strength.

A zone of partial solution heat treatment lies between the 875-800° F peak temperatures. The strength diminishes with diminishing peak temperature (and slower cooling rates) until at 800° F the edge of the overaged zone is reached.

The overaged zone is between 800 and 570° F, and in it the strength is reduced by coarsening of the precipitating phase. At 700° F, near the middle of the overaged zone and 0.3 in. from the weld, is found the most harmful combination of peak temperature, time at temperature and cooling rate so that the strength is a minimum. Tensile failure usually occurs here.

At temperatures of exposure lower than 570° F, the base metal retains full response to aging. At about 500° F a hump invariably shows in the hardness surveys where the hardness is actually higher than that of the unaffected base metal. Until further investigation is made, only conjectures could be given as to the cause of this.

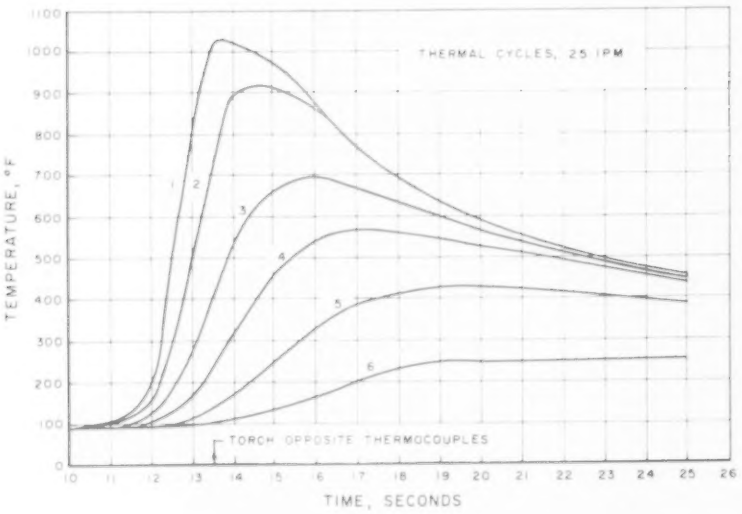

Fig. 6 Thermal cycles of the joint shown in Figs. 5 and 7. Base metal at thermocouples 1 (nearest the weld) and 2 upon aging had full strength; at 3 it had minimum strength; and at 4, 5 and 6 it had full strength, being unaffected by welding heat

Thermal Cycles During Welding

In order to obtain thermal-cycle curves, temperature surveys were made by using thermocouples buried in the plate and which fed into a recording oscillograph. To summarize the results from these curves it can be said that the maximum temperature reached by the softest part of the heat-affected zone did not vary much with change in welding speed. Overaging therefore was related not so much to temperature as it was to the time spent in some harmful temperature range. This range appeared to be 570 to 700° F, approximately.

In the experiment, iron-constantan thermocouples were peened into small holes located near the middle of the ½-in. plate at these distances from the weld centerline: 0.15, 0.25, 0.45, 0.65, 0.95 and 1.45 in. The plate was thermally insulated from the jig with asbestos tape to widen the heat-affected zones. Plates were prepared and welds made at speeds from 4 to 50 ipm.

Figure 6 shows the family of thermal curves for a 25 ipm weld and Fig. 7 completes the data for the same weld, plotting hardness and peak temperature against distance from weld. Hardness both as-welded and after aging are given to show how weld and base metal respond to aging.

In comparing thermal-cycle curves of different speeds (not shown) it was noted that the softest part of the overaged zone always reached a peak or maximum temperature close to 700° F. Actually, it varied somewhat with speed; at 4 ipm it was 675° F, at 20 it was 700, at 40 it was 720, and at 50 ipm it was 750° F.

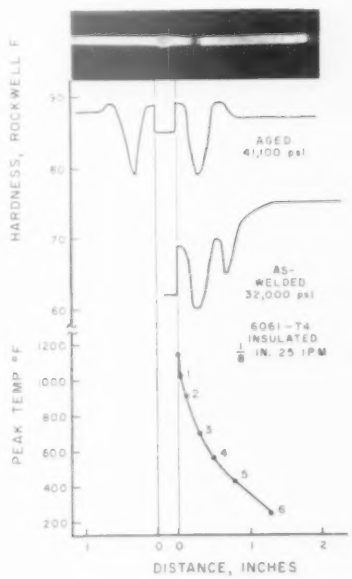

Fig. 7 Hardness surveys, as-welded and aged, of a 25 ipm weld in 6061-T4; also the curve relating base-metal peak temperature to distance from weld

Since the peak temperature of the softest zone did not vary much with respect to welding speed, it is concluded that the amount of softening (overaging)

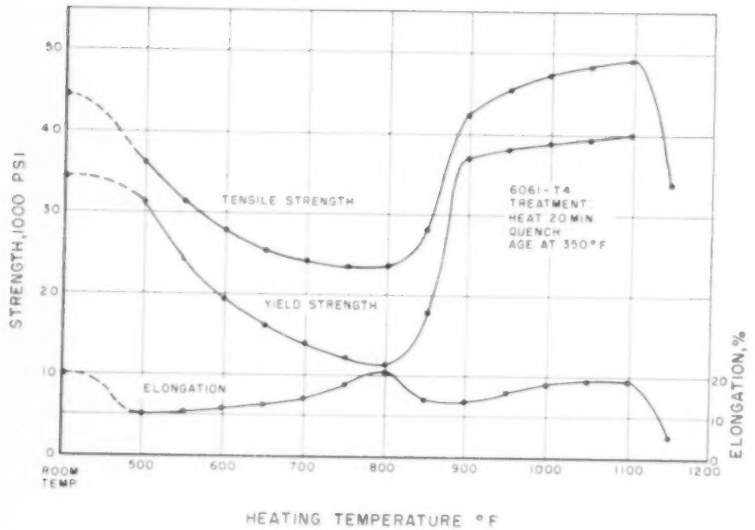

Fig. 8 Effect of heating on mechanical properties of 6061-T4 base metal. Heated to various temperatures for 20 min, then quenched and aged

was less dependent on temperature than it was on the time spent in some range of harmful temperature. From the thermal curves, Fig. 6, this range appears to be from 570 to 700° F, approximately. In that figure traces of thermocouples 1 and 2 represent practically the borders of the zone that was solution treated and was fully responsive to aging. Trace 3, with a peak of 700° F, happens to be at the worst of the overaged zone, and trace 4, with a peak of 570° F, is in relatively unaffected base metal so the principal overaging is between 570 and 700° F.

The time in the critical 570–700° F range is determined by the welding speed and was found to be almost inversely proportional to the speed. This implies that at slow speeds the time within the critical range is increased markedly and the overaging likewise increases markedly. This is confirmed by the speed versus strength tests described later.

It was found that welding speed had no effect on the peak temperature reached at any selected point in the base metal. In other words, the curve in Fig. 7 of peak temperature versus distance held true for speeds from 4 to 50 ipm within the distance surveyed, 1.3 in. The shape of this curve, while unaffected by speed, would of course be altered by changes in plate geometry and chilling rate. Since one curve suffices for all speeds, then it follows that the softest zone, which was said to occur at slightly higher temperature with higher speed, would move slightly toward the weld with higher speed.

The observations on the 570–700° F range appear to correlate with the work of Lemon[2] who found that on quenching 6061 from 970° F the cooling rate between 700 and 500° F was the most critical with respect to the hardening capacity. Even though his specimen was cooled through this range and ours was heated into it, there is a similarity of heat treatments in that both specimens were in a solution heat-treated condition prior to entering this range and hence were susceptible to overaging. He found the cooling rate between 700–500° F must be faster than 20° F/sec. This rate might be restated as a maximum time of 10 sec in the 500–700° F range. Our trace 3 (of the softest zone) existed only 8 sec in this range and, as might be predicted, good strength was attained. At slower speeds the time would be longer and at 20 ipm (below which the strength was found to drop rapidly) it might be possible to show that the critical time had been exceeded.

Overaging of Base Metal

Samples of 6061-T4 base metal were heated to a variety of temperatures for 20 min, then quenched and aged at 350° F for 8 hr. These were tested for mechanical properties and examined metallographically in order to see if there was a similarity between base metal heated for a long time and the weld heat-affected zones which had been heated to the same temperatures, but for a short time (2 to 10 sec). In general, a similarity was found.

In Fig. 8 the mechanical properties of the base metal are plotted against heating temperature. It will be seen that strength dropped with increasing exposure temperature and reached a minimum at 800° F. This is the counterpart of the weld joint minimum found at 700° F. The overaging range was from 500 to 800° F and the effects were visible in the microstructure as a dot-like precipitate of Mg_2Si, most of which was in the grain boundaries.

At 850° F there was partial solution heat treatment and some pickup in strength. At 900° F and above this solution heat treatment was complete, and full strength was developed. This agrees with the condition in the welded joint where full strength was developed above 875° F. The microstructures from 950 through 1100° F were similar to the normal -T6 microstructure. At 1150° F there was grain growth and boundary melting resembling, to an exaggerated degree, the fusion zone at the edge of the weld.

Welding Factors Affecting Joint Strength

Described in this section are the tests of the effects of welding speed, heat input, rewelds and other factors related to joint strength. As used here, strength refers to that obtained after aging since the strength of -T4 or -T6 in the as-welded condition is low regardless of welding conditions. From these data welding procedure requirements were set up to insure adequate joints on the production tanks. Unless noted otherwise, the tests used $\frac{1}{4}$-in. 6061-T4, with chilled jig and argon shielding gas.

Welding Speed and Heat Input

Welding speed was the most significant factor influencing the strength (i.e., response to aging). The strength at slow speeds is low, but it rises rapidly with increasing speed up to a certain speed after which the improvement is slight. The uppermost curve in Fig. 9 illustrates the speed-to-strength relation for $\frac{1}{4}$-in. 6061-T4. The curve breaks or levels off at 15 ipm; above this speed the joint strength is about 95% of the unwelded base-metal strength.

This break occurs at what was suggested in an earlier paragraph as a critical speed, above which the overaging heat effects practically will not occur because there is insufficient time in the 570–700° F temperature range. The critical speed for $\frac{1}{8}$-in. gage was 10 or 12 ipm; for $\frac{1}{2}$ in. it could not be determined.

The benefit of higher welding speeds was found to be readily explainable in terms of the heat-input measurements.

Heat input as used here is defined[3] as energy input per inch of weld. The formula for it is:

$$\text{Heat input (Joules per inch or watt-seconds per inch)} = \frac{\text{Arc volts} \times \text{amperes} \times 60 \times \text{power factor}}{\text{Speed, ipm}}$$

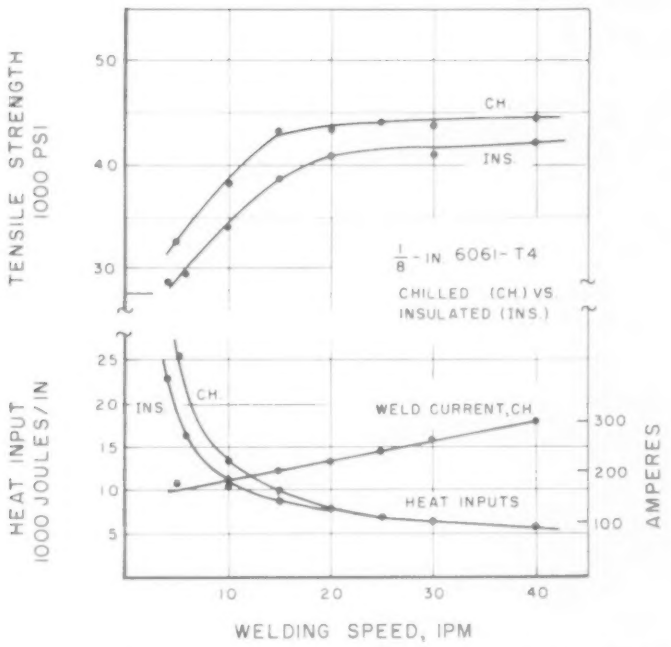

Fig. 9 Effect of welding speed on tensile strength and heat input for $\frac{1}{8}$-in. 6061-T4. Also compares results for plates insulated from jig with plates chilled by jig

When heat input is plotted against travel speed, bottom of Fig. 9, it is readily seen that the heat input is very high at slow speed. As the speed increases, the input curve drops sharply, then levels out and approaches the heat input needed solely to melt the weld bead.

To explain why heat input is lower at higher speeds, it might be said that there is less time for the heat to flow out into the plate and into the jaws of the fixture. Therefore, a higher proportion of the heat is usefully employed in making the weld. The principal benefit, as far as we are concerned, is not economy but that the base metal in being heated less will cool more quickly. Thus it will retain more of its -T4 properties since it is in the overaging temperature range a shorter time.

Although the heat input drops with increasing speeds, it is true that the welding current must be raised. This current increase is slight, however, compared to the increase in speed. As plotted in Fig. 9, the amperage shows a straight-line increase with speed. From the slope it can be calculated that a 47% increase in current allows a 600% increase in speed.

The strength of the heat-affected zone depends almost solely on the welding speed; even the kind of shielding gas or degree of chilling is relatively unimportant. Likewise, heat input is practically determined by the speed since it can be seen that most of the terms in the above input formula (other than speed) are relatively fixed and even the amperage can be varied scarcely 5% at a given speed without causing unsatisfactory penetration. Therefore, once the speed-strength relation for a given setup is determined, the strength of the soft zone can be assured by setting a minimum-speed requirement. (This assumes that the weld is single pass. A repair weld will add to the heat effect.)

Chilling by Jig

The effect of two widely different degrees of quenching by the jig were studied. In the more severe chill the plates were in contact with the conventional water-cooled copper hold-downs. In the other, the plates were thermally insulated from the jig by $\frac{1}{8}$-in. asbestos tape placed above and below them. The insulated jig represented a condition of quench much slower than likely to be met in any production jig.

The curves of strength versus speed, Fig. 9, for chilled and insulated plates show that the insulated weld was about 2000 psi weaker in the useful welding range (above 20 ipm). The fact that the curves lie as close as they do shows that most of the quenching is via heat flow into the plate itself rather than into the jig. This is verified by the heat input curves, bottom of same Fig. 9, which are essentially the same except at the lowest speeds. It can be added that the welding amperage was about the same, regardless of degree of chill.

As might be expected, when the plate is chilled, the heat-affected zone is narrowed, it has a higher minimum hardness and it is shifted closer to the weld. Figures 7 and 10 can be compared to illustrate this.

Strength of Weld Metal

The weld contains enough base metal to make it susceptible to age hardening to practically -T6 strength. This is illustrated in the various hardness surveys across the welded joints in this report. When the section at the weld was reduced enough to cause failure in the weld, strengths of 42,000 to 45,000 psi were developed. Of the tensile tests reported herein, all broke in the soft part of the heat-affected zone except for some of the $\frac{1}{8}$-in. welds and the 40 ipm helium run. The latter broke along the weld centerline because of root porosity.

Admittedly, with the high joint efficiencies, it becomes necessary to maintain high weld-metal quality. But the same level of quality would be needed whether the joint is fully heat treated after welding as in the conventional procedure or simply aged as in this investigation.

Manual Welds

Manual welds produce heat-affected zones with strengths no greater than that of a 5 to 6 ipm machine weld. Tensile strengths obtained on manually welded $\frac{1}{8}$-in. joints were from 22,000 to 29,200 psi. Manual welds could not be used, therefore, on joints requiring high strength nor could extensive manual repairs be allowed on such joints. Manual welding is usually acceptable for welding small bosses and attach-

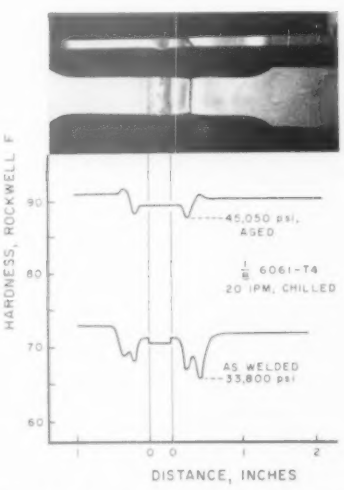

Fig. 10 A weld in 6061-T4 which after aging developed 97% of the tensile strength (46,800 psi) of the fully heat-treated base metal; $\frac{1}{8}$-in. sheet welded at 20 ipm

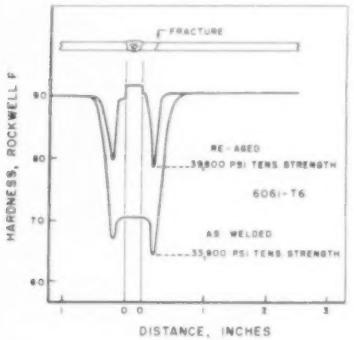

Fig. 11 A weld in 6061-T6 which after aging had only 85% of the base-metal tensile strength. To be compared with the -T4 weld, Fig. 10

ments where the localized softening can be tolerated.

Rewelding

Inspection by X-ray of all welds is done at such intervals that a joint can be repaired, if necessary, on the mechanical welding fixture for that joint. This is before the tank is aged.

Each reweld lowers the strength of the heat-affected zone since the effect is cumulative. Tests showed that a joint of 45,050 psi tensile strength dropped upon remelting of the bead into the range of 41,800-37,000 psi depending on whether the amperage used for the remelt was the same as the original or slightly higher. An additional reweld can drop it to 34,200 psi; the acceptability of this would depend on repair size and location.

Helium Shielding Gas Versus Argon

To compare welds made with helium shielding gas with those of argon a set of tests was made on $\frac{1}{4}$-in. sheet duplicating those for argon reported earlier. The curves for helium are not shown since for both input and strength they were practically the same as those for argon. Several comparisons will be made.

For a given speed the heat inputs were almost exactly the same, helium being about 3% less than argon. Since the arc voltage for best arc performance with helium was 21 v and that for argon was 13 v, the currents required were in inverse proportion to this ratio (which they had to be in order to give equal heat inputs). In other words, 210 amp with argon was needed to duplicate the fusion of 130 amp with helium.

The joint strengths with helium shielding are substantially the same as those with argon at the same speed. The helium strengths were either the same, or in some instances 2% lower.

The helium-shielded welds had more porosity and the 40 ipm run broke in the weld from heavy centerline porosity. This could be improved by adjustments of the arc voltage and particularly by increasing the helium-gas flow rate since it was set at only 50% over the usual argon rate, whereas an increase of 2 to 3 times is often recommended.[4] Helium-shielded welds on $\frac{1}{4}$-in. plate used high gas flow (100 cfh) and were sound.

Other comparisons of the merits of helium versus argon and mixtures thereof as shielding gases are outside the scope of this paper and have been well reported in the literature.[5]

Welds in 6061-T6

Welding and reaging of 6061-T6 did not give as good strength as the same procedure on 6061-T4. Figure 11 shows that the -T6 had 39,800 psi tensile strength; 6061-T4 had 45,050 psi when welded under the same conditions ($\frac{1}{4}$-in. sheet, 20 ipm, chilled fixture). Note how reaging of the 6061-T6 after welding has improved the strength of both the weld and the heat-affected zone.

Welds in $\frac{1}{16}$-In. and $\frac{1}{4}$-In. Gage

For $\frac{1}{4}$-in. 6061-T4 the curves in Fig. 12 for strength and heat input verify the conclusions made for $\frac{1}{4}$-in. gage. The higher tensile strength (47,500 psi) of the joints reflects the higher strength often obtained in thinner-gage base metal.

The $\frac{1}{4}$-in. plate is the thickest gage used in the production tank. Helium rather than argon gas was used for this set of runs to raise the effective heat output of the 400-amp power supply and allow higher travel speeds. Fig. 12. Even so, the top speed attainable was 25 ipm, taking 405 amp. This leaves the input curve unfinished with respect to showing the nearly flat part of it. The weld was single pass with a square butt joint.

To better ascertain whether the weld metal strength was adequate in this heaviest gage, the weld reinforcement was ground off. Even so, the joint failed in the heat-affected zone of the base metal on half of the test bars and in the weld on others.

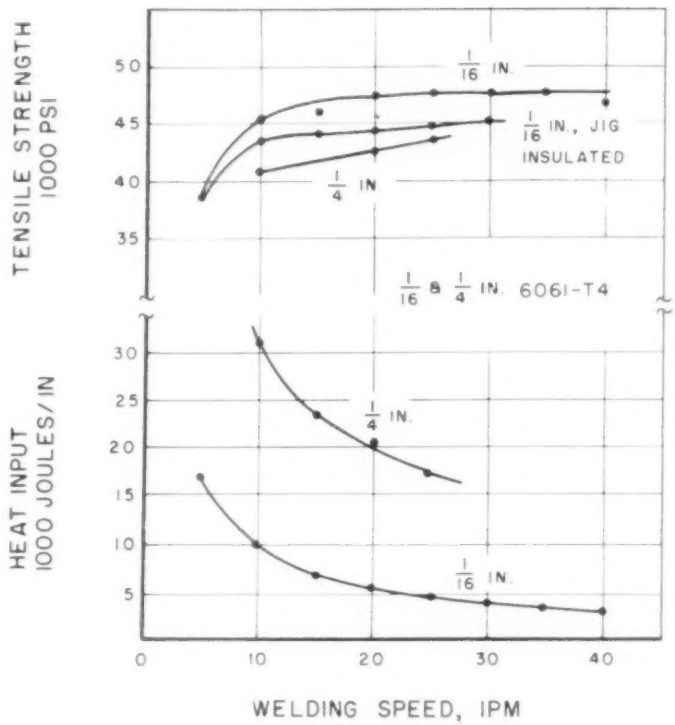

Fig. 12 Effect of welding speed on tensile strength and heat input for $\frac{1}{16}$- and $\frac{1}{4}$-in. 6061-T4

Production Tank Making

At the outset of the program to make these tanks there were two main questions: whether the manufacturing difficulties could be overcome and whether high strength and uniformity could be maintained in the joints.

The laboratory investigation reported here showed that high strength was achievable and indicated what factors were significant. Since strength was related closely to speed, minimum welding speeds for principal welds were set up as part of the specifications: 18 ipm for gages under 0.187 in. and 10 ipm for 0.250 in. Mechanical welding equipment was specified since the inadequacy of manual welding was ap-

parent with respect to uniformity of quality as well as to speed.

The effect of manual repairs in drastically lowering joint strength made it necessary to limit these to 3 in. in any 15 in. of weld on the principal joints. Present practice is to reweld by machine rather than manually.

The production welding equipment does not have automatic arc-length control but instead has manual adjustments. The current is ac and for the shielding gas argon-helium mixtures are becoming favored over argon.

Concurrent with this laboratory investigation, there was development of fixturing and techniques by the manufacturer of the tanks to achieve dimensional accuracy. Also, there was refinement of the design leading to a tank in which all principal joints were butt joints and all were machine welded.

The difficulty of making extensive reworks makes it necessary that high quality of workmanship be maintained at all stages of production.

Conclusions

It has been shown that 6061-T4 aluminum alloy can be fusion welded and then aged to achieve a joint strength practically equal to joints that have been fully heat treated after welding.

In the base metal about $\frac{1}{4}$ in. from the weld, there is an overaged zone in which the failure under tensile stress will usually occur. The weakening or softening of this zone is related to several factors, of which welding speed was the single most significant one since this governs the heat input into the weld and the surrounding base metal. The heat input in turn determines the thermal cycle of the heat-affected zone.

The length of time that the base metal was heated in the 570-700° F range was critical with respect to overaging or softening. With increasing speeds, this time was reduced.

As welding speed is increased, the joint strength improved rapidly up to a speed of about 15 ipm; at higher speeds, the improvement is less pronounced. The heat-input curve is almost a mirror-image of the strength curve, input being high at low speeds, dropping quickly as speed increases and tending to level off above 15 ipm.

Adequate chilling by the jig helped improve strength but to a relatively small degree compared to the improvement from higher speed. Helium gas did not differ from argon with respect to strength and heat input at a given speed. It did require less amperage and would be advantageous where the current output of the welder was inadequate.

Manual welding will seriously lower the strength of the heat-affected zone. It cannot be used on any principal structural welds, and for repairs of such welds the size and number of manual repairs must be limited.

The fabrication sequence of making tanks from 6061-T4 and then aging has proved feasible. Typical tensile strengths from three tanks are: 38,700 psi (early tank), 42,200 psi and 42,400 psi. These strengths approach the 45,000 typical of 6061-T6 and show what can be achieved with this sequence provided one has rigid process control and excellent fixtures.

Acknowledgment

The author wishes to express his appreciation for the cooperation given by G. F. Kappelt, chief metallurgist, and E. A. Dolega and A. Nathan of the Metallurgical Laboratory of Bell Aircraft Corp., Buffalo, N. Y. Technicians who assisted were C. Chiappone and E. Sirmay. Much of this work was done under an Air Force contract and the permission to publish this is appreciated. The cooperation of J. R. Schadt of the Bell Tank Design Unit and L. E. Campbell of Benson Manufacturing Co., Kansas City, Mo., is also gratefully acknowledged.

References

1. Mann, H. D., and Pokhisser, R. E., "Automatic Inert-Gas-Shielded Tungsten-Arc Welding of Aluminum Alloys," THE WELDING JOURNAL, 36 (8), 790-797 (1957).

2. Lemon, R. C., and Hunsicker, H. Y., "Effects of Quenching Rate and Quench-Aging on the Tensile Properties of Aluminum Alloy 61S," *Trans. Am. Soc. Metals*, 42, 357-375 (1950).

3. Smith, R. D., and Dorn, W. D., *Weldability of Steels*, Welding Research Council (1953).

4. Helmdrecht, W. H., and Oyler, G. W., "Shielding Gases for Inert Gas Welding," THE WELDING JOURNAL, 36 (10), 969-979 (1957).

5. Dowd, J. D., "Inert Shielding Gases for Welding Aluminum," *Ibid.*, 35 (4), Research Suppl., 207-s to 210-s (1956).

Table 1—Summary of Tests of Welded-Then-Aged 6061-T4 Aluminum

Conditions	*Welding speed, ipm*	*Current, amp*	*Heat input, joules/in.**	*Tensile strength, psi*	*Elongation, % in 2 in.*
Base metal, $\frac{1}{4}$ in. (several heats)				(45,400 to 46,800)	16
Argon gas, $\frac{1}{4}$-in. chilled plate	5	180	25,600	32,700	3
	10	185	13,100	38,200	3
	15	210	9,950	43,250	6
	20	220	7,800	43,200	5
	25	245	6,950	44,000	5
	30	265	6,280	43,450	6
	40	300	5,320	44,300	7
Argon gas, $\frac{1}{4}$-in. insulated plate	4	130	23,100	28,700	4
	6	140	16,500	29,400	4
	10	150	10,650	33,900	4
	15	185	8,750	38,600	6
	20	220	7,800	40,900	7
	30	290	6,880	40,900	8
	40	330	5,850	42,000	9
	50	330	4,680	42,600	8
Argon gas, $\frac{1}{16}$-in. chilled plate	5	118	16,700	38,300	3
	10	136	9,650	45,400	4
	15	140	6,600	45,900	5
	20	154	5,450	47,300	9
	25	160	4,550	47,500	7
	30	164	3,900	47,300	8
	35	172	3,500	47,400	10
	40	175	3,100	46,700	9
Argon gas, $\frac{1}{16}$-in. insulated plate	5			38,500	3
	10			43,700	3
	15			43,900	3
	20			44,100	3
	30			45,100	3
Helium gas, $\frac{1}{4}$-in. chilled plate	5	113	24,200	34,100	4
	10	117	12,500	39,200	4
	15	122	8,700	41,900	5
	20	140	7,500	42,800	7
	25	150	6,450	42,500	6
	30	170	6,100	43,900	5
	40	205	5,300	43,600	2
Helium gas, $\frac{1}{4}$-in. chilled plate	10	290	31,000	40,900	5
	15	325	23,200		
	20	380	20,300	42,850	5
	25	405	17,300	43,600	6

* Heat input, for argon gas = amp × 13 v × 60 × 0.91 power factor/speed, ipm. Heat input, for helium gas = amp × 21 v × 60 × 0.85 power factor/speed, ipm.

GENERAL NOTE: Weld reinforcement was left on all tensile specimens except the $\frac{1}{4}$-in. gage. Fractures were in base metal soft zone except on $\frac{1}{4}$-in. helium 40 ipm weld and on half of the $\frac{1}{4}$-in. welds where fracture was in weld metal.

THE INFLUENCE OF FERRITE BANDING ON THE IMPACT PROPERTIES OF MILD STEEL

Charpy properties of a severely banded ferrite-pearlite structure compared with those of a random ferrite-pearlite distribution

BY W. S. OWEN, MORRIS COHEN AND B. L. AVERBACH

ABSTRACT. The object of this investigation was to compare the Charpy properties of a severely banded ferrite-pearlite structure with those of a random ferrite-pearlite distribution. Both types of specimens could be prepared from the same material by applying suitable homogenizing treatments to an initially banded steel. Some observations on the nature of the banding are described.

The Charpy properties at the lower end of the testing-temperature range are not appreciably affected by the degree of ferrite banding, by the direction of the specimen axis, or by the orientation of the notch. However, in the higher temperature range, the random structure exhibits a higher energy absorption than does the banded structure and, in both cases, the Charpy values depend strongly on the orientation of both the specimen and the notch. Evidence was obtained to suggest that the fracture appearance is not sensitive to specimen orientation even in a severely banded steel, although notch orientation is a factor.

No preferred crystallographic orientation of the ferrite was found in any of the specimens.

Introduction

There is good reason to suppose that the fracture properties of mild steel can be influenced by the texture of the microstructure. In discussing the condition for crack propagation

$$\sigma \geq \left(\frac{E p}{c}\right)^{\frac{1}{2}}$$

where

σ = normal stress needed for crack propagation.
E = Young's modulus.
c = crack length.
p = plastic work required for the formation of unit area of surface.

Orowan[1] has suggested a number of ways in which p, and consequently σ, might be increased. One of these involved laminating the plate by incorporating layers of either a weak or a highly ductile material. A weak layer, such as slag, should act by bursting open ahead of the crack, annihilating the triaxiality, and causing some fibrous fracture to occur before the necessary triaxiality for brittle fracture can be reestablished. Alternatively, an increase in p can be achieved by rolling thin layers of a tough metal into the plate. Unfortunately, it is very difficult to obtain precise values of p for different materials under the conditions envisaged here, and thus no accurate estimate of the quantitative effect is possible. If it is assumed that the values of ferrite and pearlite are appreciably different, ferrite banding in mild steel is a form of lamination which should influence the fracture properties. Several experimental studies have been made of the effect of ferrite-pearlite banding on the impact properties, but the results are somewhat ambiguous.

Mattos-Sjoberg[2] compared the notch-bar properties of two similar steels with different degrees of banding, and concluded that a lower transition temperature was associated with the finer banding. However, Tipper[3] has also investigated this problem on the same steels. Pellini[4] reported that in numerous tests of banded steels only one with wide bands of severe alloy segregation showed increased resistance to brittle fracture. In contradistinction, Mangio and Boulger[5] concluded that a banded microstructure is less resistant to brittle fracture than a uniform unbanded structure. In support of this statement, they quoted the work of Sims, Banta and Waters[6] who compared high-tensile steel plates rolled from slabs of the same ingot, one slab being given an intermediate homogenizing treatment for ten hours at 2350° F. Homogenizing the slab lowered the 10 ft-lb Charpy V-notch transition temperature of the plate by about 60° F. However, in the original report,[6] it was stated that the "... microstructure of the annealed plate rolled from the homogenized slabs showed strong evidence of banding and no influence of the homogenizing treatment." Thus, it seems questionable to ascribe the improvement in transition temperature to a change in the extent of banding.

In a study of the quantitative relations between Charpy impact properties and microstructure, Owen, Whitmore, Cohen and Averbach[7] deduced that effects due to banding were insignificant compared with those due to other microstructural parameters. The present experiments were prompted by a desire to obtain more direct information on this elusive subject.

Since the ferrite-pearlite banding lies parallel to the rolling direction, a correlation between such banding and the anistropic properties of hot-rolled plate might be expected. Directional effects are most apparent in notch-bar impact tests.[8] Troiano and Klinger[9] used a V-notch Charpy test to study the directionality of mechanical properties in hot-worked steels, and concluded that there is no directional effect in the brittle range (below the 10 ft-lb level), ductility being the only basic property that exhibits an isotropy. Jatczak, Girardi and Rowland[10] showed that the only property improved by homogenizing a banded 4340 steel was the transverse ductility, and the resultant improvement was commercially insignificant.

Production of Random Ferrite-Pearlite Structures

All of the experiments were performed on a semikilled ABS Class B steel supplied in the form of ¾-in. hot-rolled plate. The analysis and room-temperature mechanical properties are given in Table 1.

In line with previous work on this steel, two parameters were used to describe the degree of the banding: (*a*) the ratio of the average pearlite linear

W. S. Owen is associated with the University of Liverpool, England. Morris Cohen and B. L. Averbach are associated with the Department of Metallurgy at Massachusetts Institute of Technology, Cambridge, Mass.

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intercept, β, measured parallel and perpendicular to the rolling surface, and (b) the ratio of a mean ferrite path, α_2, measured in the same two directions. α_2 is the mean ferrite intercept made by the ferrite-pearlite boundaries along straight-line transverses, the ferrite-ferrite boundaries being ignored. The measurements were conducted on sections transverse to the rolling direction.

In hypoeutectoid steels, the metallographic banding pattern is established during the proeutectoid separation of ferrite and the resulting segregation of the carbon in the pearlite-rich regions. Thus, it is not surprising that both the austenitizing temperature and the cooling rate have a pronounced effect. The former effect is shown by the data in Fig. 1. In this series, all the annealing treatments were carried out with the same slow cooling rate (about 1.5° C per min), and the banding is found to be a function of the austenitizing temperature, the severity increasing from 850 to 900° C and then decreasing as the temperature is further increased above 1050° C. The initial increase may be irrelevant, because it depends only upon the low value obtained at 850° C, and from other experience with this steel it is suspected that this temperature is slightly below A_1. After annealing for 1 hr at 1250° C, the banding was almost completely eliminated.

Table 1—Chemical Composition and Room-Temperature Properties of the As-Received Plate

C	0.16
Mn	0.60
P	0.014
S	0.028
Si	0.022
Cu	0.028
Al	0.042
Elastic limit, 10^3 psi	22.0
Upper yield point, 10^3 psi	33.0
Lower yield point, 10^3 psi	31.0
Elongation, %	30.9
Reduction in area, %	58.2

The as-received specimen was less severely banded than those annealed between 900 and 1050° C (Fig. 1). This is probably due to the cooling rate of the plate from the rolling temperature being somewhat faster than that of the annealed specimens. An example of the effect of cooling rate is shown in Fig. 2 in which the microstructure on transverse sections of a specimen furnace cooled (1.5° C per min) from 950° C is compared with that of a specimen air cooled (150° C per min) from the same temperature.

Jatczak, Girardi and Rowland,[9] studying alloy steels, concluded that chemical heterogeneity is the primary cause of banding. Ignoring the 850° C point in Fig. 1, the decrease in banding with increase in austenitizing temperature is consistent with this view. Further, it was found that the extent to which banding was reduced by annealing at a high austenitizing temperature was a function of the time at temperature. To show the time effect, it was necessary to use a method of developing banding suggested by the treatments of Jatczak, *et al.*[10] After austenitizing at the temperature under investigation, the specimen was air cooled to room temperature and then reheated to 900–950° C which is the temperature range most propitious for the development of

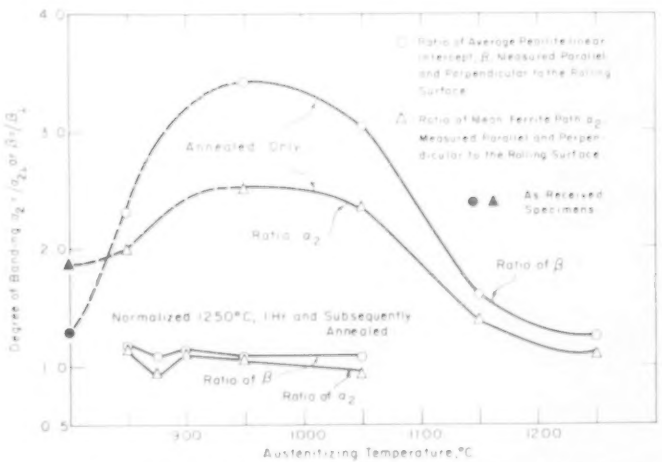
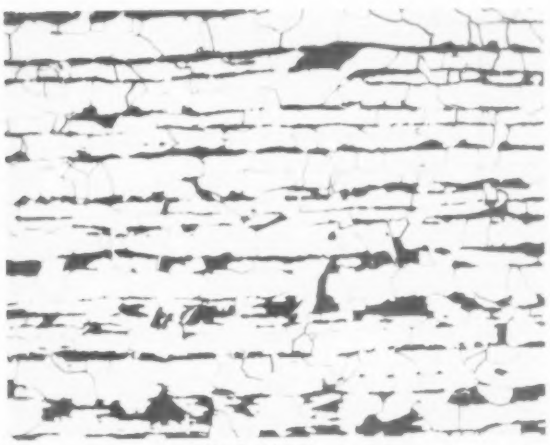
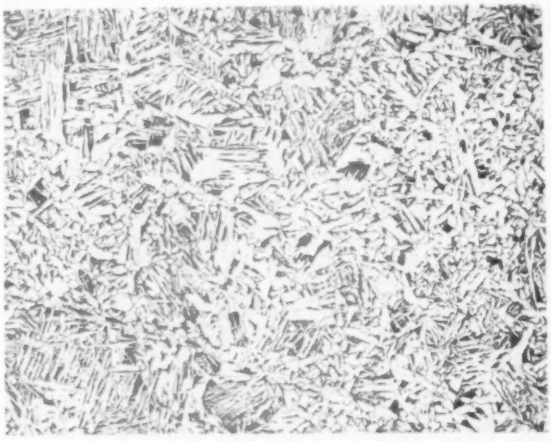

Ratio of Average Pearlite-Linear Intercept, β, Measured Parallel and Perpendicular to the Rolling Surface
Ratio of Mean Ferrite Path α_2 Measured Parallel and Perpendicular to the Rolling Surface
As Received Specimens
Annealed Only
Ratio α_2
Ratio of β
Normalized 1250°C, 1Hr and Subsequently Annealed
Ratio of β
Ratio of α_2
Degree of Banding $\alpha_2^{\parallel}/\alpha_2^{\perp}$ or $\beta^{\perp}/\beta^{\parallel}$
Austenitizing Temperature, °C

Fig. 1 The effect of heat treatment on the severity of banding as revealed by two different microscopic parameters

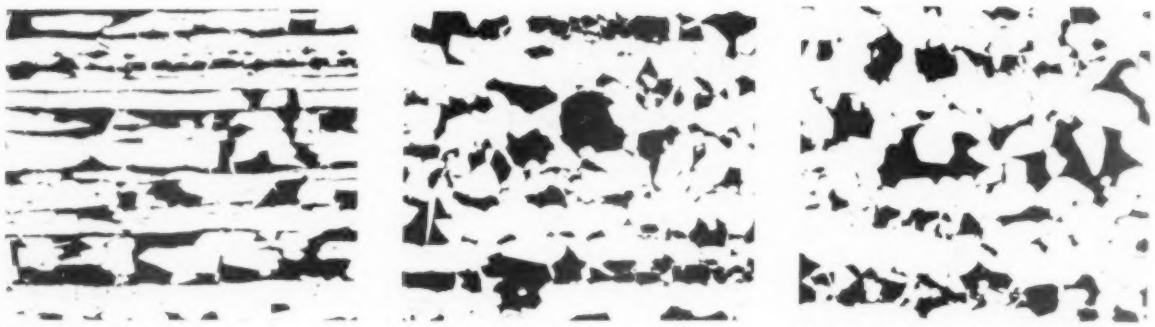


(a) 950° C, 1 hr, furnace cool



(b) 950° C, 1 hr, air cool

Fig. 2 Effect of cooling rate on distribution of ferrite. Transverse. X 100. (Reduced by $\frac{1}{3}$, upon reproduction)



(a) 0 hr—1250° C, A.C.
900° C—1 hr, F.C.
750° C—1 hr, W.Q.
350° C—1 hr, A.C.

(b) 1 hr—1250° C, A.C.
900° C—1 hr, F.C.
750° C—1 hr, W.Q.
350° C—1 hr, A.C.

(c) 2 hr—1250° C, A.C.
900° C—1 hr, F.C.
750° C—1 hr, W.Q.
350° C—1 hr, A.C.

Fig. 3 Effect of time at 1250° C on ferrite-pearlite distribution. Transverse. X100. (Reduced by 1/3 upon reproduction)

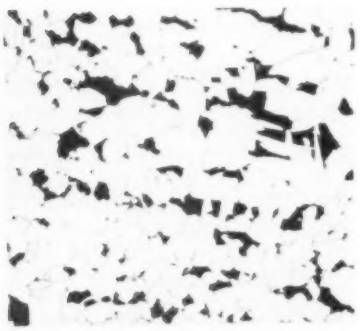


Fig. 4 Mixed ferrite grain size. Specimen heat treated 1250° C, 1 hr, furnace cooled; 875° C, 1 hr, furnace cooled. X 100. (Reduced by 1/3 upon reproduction)

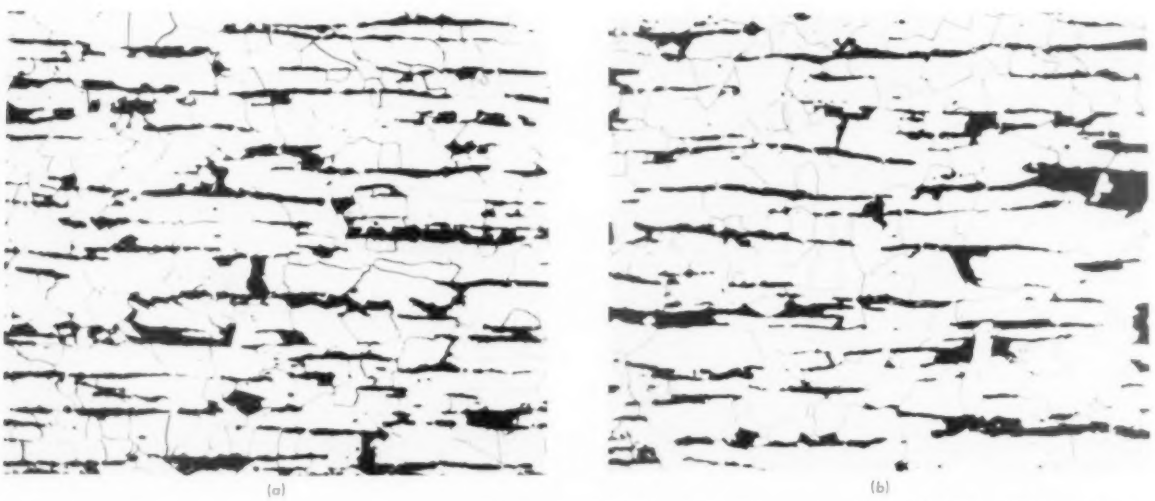
banding. After 1 hr at 1000° C, the specimen was cooled to a temperature in the two-phase region and held for an hour after which it was quenched. By trying various final temperatures, it was established that the banding due to the carbon redistribution could be seen most clearly when 750° C was employed. Finally, the specimens were tempered at 350° C for 1 hr.

In Fig. 3, microstructures are shown of specimens which had been normalized at 0, 1 and 2 hr at 1250° C before being given the special treatment. The banded structure breaks up progressively as the time at 1250° C is increased, but even after 2 hr some evidence of banding can be seen. It was found that 24 hr at temperature was required to eliminate all evidence of heterogeneity.

Further support for the view that the main function of the 1250° C treatment is to homogenize the distribution of alloying elements was provided by a series of experiments in which, after normalizing for 24 hr at 1250° C, the specimens were given prolonged treatments at lower austenitizing temperatures with the object of causing the banding to return, if possible.

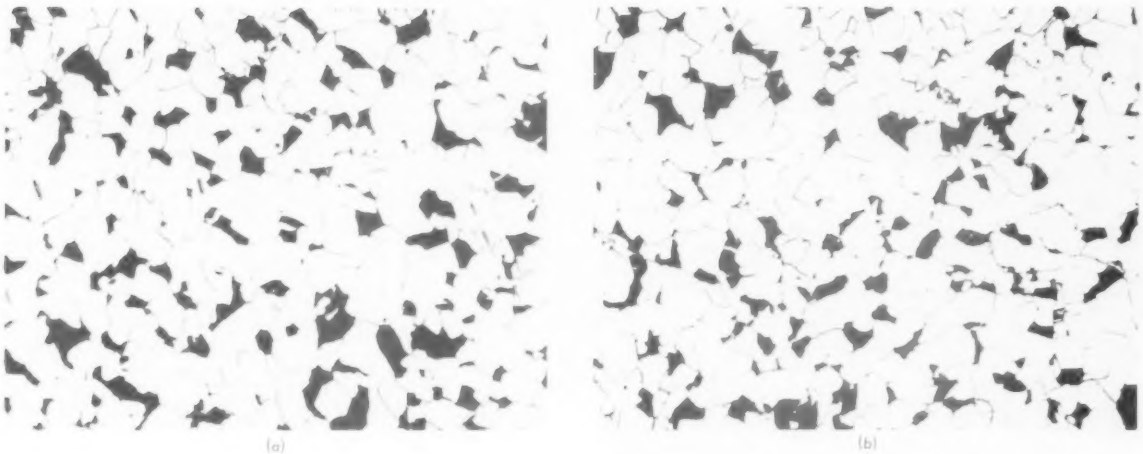
In one series, the specimen was cooled from 1250° C to a temperature of 950° C which was maintained for as long as 24 hr before slowly cooling to room temperature. In another sequence the specimen was air cooled from 1250° C to room temperature before reannealing at 950° C for times up to 24 hr. No treatment was found which produced any evidence of banding.

During the course of the exploratory work which led to the adoption of this treatment, a further complicating effect was encountered. It was found that, when the 1250° C homogenizing tem-



(a) (b)

Fig. 5 (a) Longitudinal and (b) transverse sections. Heat treated 950° C, 1 hr, furnace cooled. X 100. (Reduced by 1/3 upon reproduction)



(a) (b)

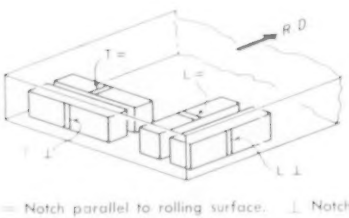
Fig. 6 (*a*) Longitudinal and (*b*) transverse sections. Heat treated 1250° C, 24 hr, oil quenched 950° C, 1 hr, furnace cooled. X 100

Table 2

	Transverse section		*Longitudinal section*	
		1250° C, 24 hr, OQ		*1250° C, 24 hr, OQ*
Parameter	*950° C, 1 hr, FC*	*950° C, 1 hr, FC*	*950° C, 1 hr, FC*	*950° C, 1 hr, FC*
Vol. fraction of ferrite, %	83	87	85	86
Vol. fraction of pearlite, %	17	13	15	14
Mean ferrite grain diameter, mm	0.072	0.071	0.077	0.067
Number of ferrite grains per mm²	5360	5360	4150	6160
ASTM No.	5.0	5.0	4.9	5.2
Pearlite banding parameter, $\beta = \beta_{\perp}$	3.42	1.03	3.43	1.02
Ferrite banding parameter, $\alpha = \alpha_{\perp}$	2.49	0.96	3.45	1.16

FC = furnace cool; OQ = oil quench.

perature was followed by annealing at temperatures below 1050° C, there was a pronounced tendency for the ferrite to develop a mixed grain size. An example of this is shown in Fig. 4. However, this tendency became less marked, the faster the cooling rate from the homogenizing temperature, and was only very slight after air cooling. To ensure a homogeneous ferrite grain size, oil quenching from the 1250° C treatment was adopted.



= Notch parallel to rolling surface. ⊥ Notch perpendicular to rolling surface.
L Specimen axis parallel to rolling direction.
R.D. Rolling direction.
T Specimen axis perpendicular to rolling direction

Fig. 7 Orientation of specimen axis and notch

Influence of Banding and Specimen Orientation on Notch-Impact Properties

In the Charpy tests, the steel in a severely banded condition (annealed 950° C, see Fig. 5 (*a*) and (*b*)) was compared with specimens which had been homogenized before the 950° C annealing, the treatment being: 1250° C, 24 hr, oil quench; 950° C, 1 hr, furnace cool. The microstructure is shown in Fig. 6 (*a*) and (*b*). A quantitative comparison of the two structures is given in Table 2. In all respects other than the distribution of ferrite and pearlite, the two structures are nearly identical.

Charpy blanks were machined from the center thickness of the plate. Four sets of specimens were prepared, two with the major axis parallel to the rolling direction and two in the transverse direction. Half the specimens of one orientation were machined with the notch parallel to the plate surface, the other half having the notch normal to the plate surface. The different orientations of specimen axis and notch, with the symbols used to distinguish them, are shown in Fig. 7.

Charpy transition curves were determined using at least thirty specimens for each curve. The curves for longitudinal specimens in the banded and unbanded conditions are shown in Fig. 8, and the corresponding curves for specimens cut transversely to the rolling direction in Fig. 9. In Fig. 10 (*a*) and (*b*) the four curves for each condition are assembled. The fracture appearance, estimated visually, is plotted as a function of the testing temperature in Fig. 11.

When a low energy-level criterion was adopted, there was no significant difference in the transition temperature between specimens of different axis or notch orientation or between the banded and unbanded steel. For example, the 10 ft-lb transition temperature was virtually unaffected by any of the geometric or microstructural variables introduced into these experiments. However, in the high-energy part of the

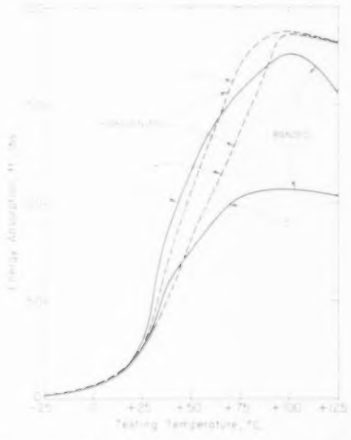


Fig. 8 Effect of homogenization on Charpy properties of specimens with specimen axis parallel to the rolling direction

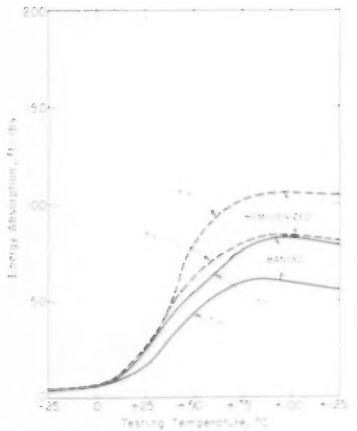


Fig. 9 Effect of homogenization on the Charpy properties of specimens with specimen axis perpendicular to the rolling direction

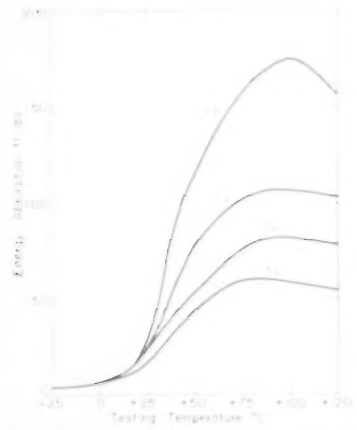


Fig. 10a Effect of specimen and notch orientation on the Charpy properties of the banded steel

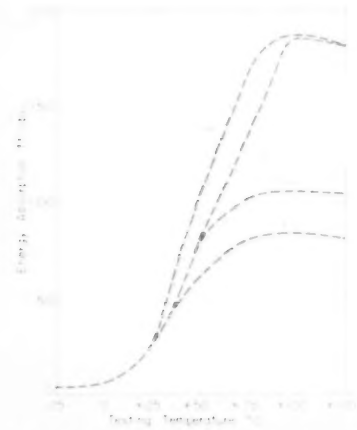


Fig. 10b Effect of specimen and notch orientation on the Charpy properties of the homogenized steel

curve, where the energy absorption is mainly due to the formation of a fibrous crack, both banding and orientation are factors.

The energy curves for the specimens with the notch parallel to the rolling surface were higher in the ductile range than those with the perpendicular notch. In transverse specimens this difference was unaffected by homogenization but in specimens with the major axis in the longitudinal direction the notch-direction effect was reduced. Among specimens of the same notch direction, the longitudinal specimens in the high-energy range were appreciably more ductile than those cut transversely to the rolling direction. This directional effect persisted in the homogenized specimens (Figs. 8, 9 and 10). Removal of the microscopic banding had a marked influence on the levels of energy absorption at the top end of the temperature range (Figs. 8 and 9); the homogenized specimens, although still anisotropic, had higher energy values than did those in the banded condition. This increase in the high-energy level and the constancy of the energy absorption in the lower temperature range resulted in a decrease in transition temperature of transverse specimens on homogenizing when an energy criterion greater than 20 ft-lb was adopted. This is illustrated by the transition temperatures at 10 ft-lb and 50 ft-lb listed in Table 3.

The fracture appearance curves are subject to an appreciable error which is difficult to assess. However, it is thought that the uncertainty is insufficient to invalidate the subsequent dis-

Table 3—The Effect of Heat Treatment on the Transition Temperature at Two Energy Levels

Direction	*Transition temperature at 10 ft-lb,* °C	*Transition temperature at 50 ft-lb,* °C
950° C, 1 hr, FC		
L ∥	11	32
L ⊥	11	55
T ∥	11	45
T ⊥	15	60
1250° C, 24 hr, 10^{-6} atm followed by 950° C, 1 hr, FC		
L ∥	9	32
L ⊥	9	38
T ∥	9	38
T ⊥	9	39

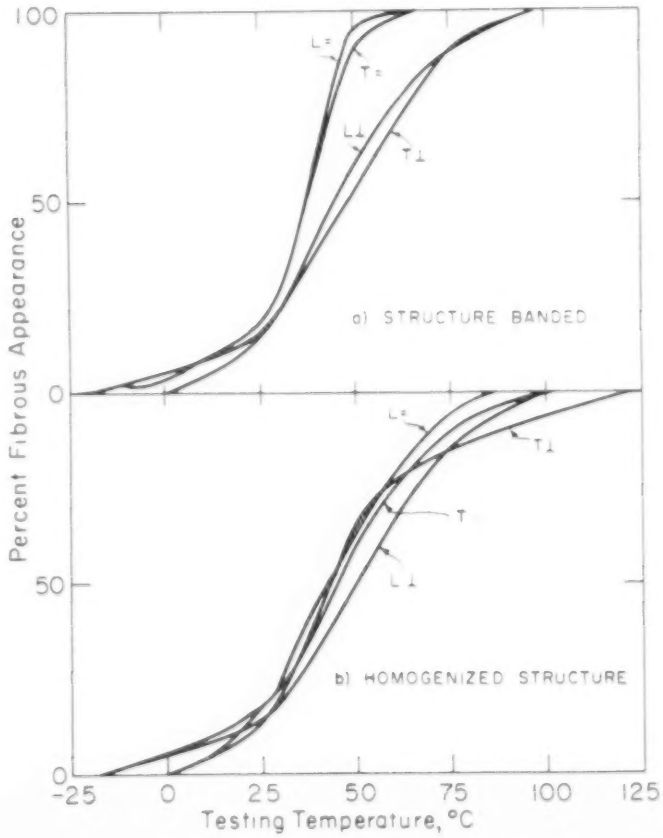


Fig. 11 Effect of homogenization on the fracture appearance

cussion. As with the energy curves, neither the distribution of the ferrite and pearlite nor the orientation of the specimen had any effect in the temperature range in which the fracture was mainly cleavage, i.e., below about 20% fibrous appearance. However, in the banded condition, the fracture appearance curves revealed an anisotropy which, unlike the effects shown by the energy curves, was removed by homogenizing. A further surprising feature was the apparently dominant effect of notch direction in the banded specimens, those with notches parallel to the surface having appreciably lower 100% fibrous transitions than those with normal notches. This contrasts sharply with the energy curves where the direction of the specimen axis relative to the rolling direction was at least as important as the notch direction.

Discussion

No experimental evidence was found to support the theoretical ideas predicting an effect of structure lamination on the brittle fracture properties. However, the Charpy test, in which the propagation of the fracture is an important feature, may not be the most suitable means of assessing the magnitude of properties which are mainly associated with fracture initiation. Possibly, low-temperature round-bar tensile tests would be more informative.

In the temperature range where the crack is predominantly fibrous, the increase in energy absorption on homogenizing is in accord with earlier observations.[9, 10] Since this increase coincides with the disappearance of ferrite-pearlite banding it is tempting to assume a cause-and-effect relationship. However, the persistence of direction effects suggests that the factors involved are more subtle than those revealed by microscopic examination.

Although previous investigators[5] have failed to disclose any preferred crystallographic orientation in the ferrite in hot-rolled plate, it was thought that if a more sensitive X-ray method for its detection could be devised, a relatively slight texture might be found to account for the anisotropic behavior. The ferrite grain size of most hot-rolled plate is such that, with stationary film and specimen back-reflection X-ray techniques, spotty and discontinuous Debye-Scherrer rings are obtained. To improve this situation a moving specimen arrangement was devised by which the crystals from at least forty different locations on the specimen surface contributed to each Debye-Scherrer ring. Banded and homogenized specimens in both longitudinal and transverse directions were examined by this technique. Representative diffraction patterns are shown in Fig. 12. No evidence of marked preferred orientation was found.

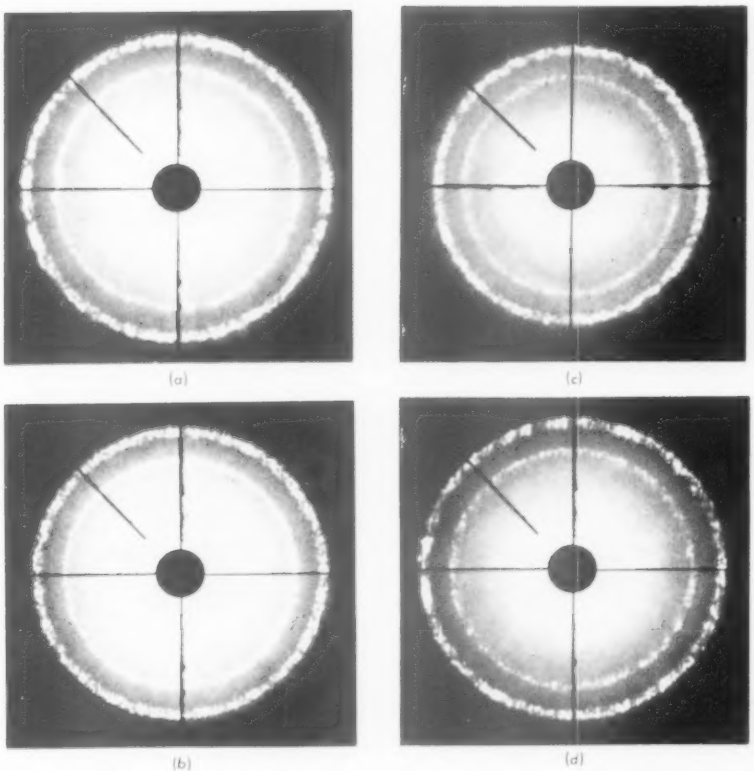


Fig. 12 (*a*), (*b*) X-ray back-reflection patterns from specimen heat treated 950° C, 1 hr, furnace cooled, banded structure. (*a*) Longitudinal, (*b*) transverse section. (*c*), (*d*) Patterns from specimens heat treated 1250° C, 24 hr, oil quenched and 950° C, 1 hr, furnace cooled, homogeneous microstructure. (*c*) Longitudinal, (*d*) transverse section

Other theories to account for the directional effect have postulated the alignment of defects, either slag inclusions or submicroscopic cracks, by the rolling operation. Tipper[2] has demonstrated the inadequacy of the submicrocrack concept. The role of inclusions warrants further consideration. Hot rolling produces laminations of nonmetallics which are parallel to the ferrite banding. Homogenizing heat treatment can remove the chemical segregation and the ferrite banding, but does not alter the distribution of inclusions. The present results can be explained if it is assumed that (1) inclusions and ferrite-pearlite laminations do not significantly alter the energy absorption of an intersecting cleavage crack; (2) both types of lamination decrease the energy absorption of a fibrous crack, but the effect of inclusions is much greater than that of the ferrite-pearlite banding; and (3) the distribution of inclusions does not affect the microscopic proportion of fibrous appearance in the fracture. The energy increase in the ductile range on homogenizing could be attributed to the redistribution of ferrite and pearlite, and the persistence of the directional effect to the stability of the nonmetallics. Assumption (3) is necessary to explain the apparent discrepancy between the change in energy absorption and the proportion of fibrous appearance with orientation and temperature. However, the experimental data relating to fracture appearance are insubstantial, and it would be unwise to elaborate these ideas without further experimental support.

Conclusions

1. Ferrite banding in reheated hot-rolled mild steel is influenced by the austenitizing temperature, the time at temperature and the cooling rate.

2. Once the banding has been completely removed by an homogenizing heat treatment, it is not reformed by thermal treatment.

3. The experimental data are consistent with the view that banding is a result of chemical heterogeneity, although the segregating elements were not identified in this investigation.

4. The brittle fracture properties as revealed by the Charpy test (that is, behavior below the 20 ft-lb or about 20% fibrous appearance level) are not affected by the extent of ferrite-pearlite laminations nor do they show any anisotropy even in severely banded plates.

5. The fibrous fracture properties are influenced by specimen and notch orientation as well as by subsequent heat treatment to a pronounced degree. At a selected testing temperature in the ductile range, both the longitudinal and transverse energy absorption is increased by an homogenizing heat treatment which removes the ferrite-pearlite banding. However, the anisotropy persists. The experimental evidence suggests that, when judged on the basis of fracture appearance only, the notch direction is important, but this directional effect is erased by the homogenizing treatment.

6. Preferred crystallographic orientation of the ferrite is not a factor in these phenomena.

References

1. Orowan, E., Communication to the Ship Structure Committee.

2. Matton-Sjoberg, P., "The Mechanism of Fracture in Impact Tests," *J. West. Scot. Iron Steel Inst.*, **60**, 180 (1952-53).

3. Tipper, C. F., "Tests on Two Samples of Steel Received from Dommarrets Jernwerk, Sweden," Report FE4 741, Admiralty Ship Welding Committee (November 1952).

4. Pellini, W. S., Private communication reported in Reference 5.

5. Mangio, C. A., and Rodiger, F. W., "The Effect of Variations in Texture on Energy Absorption and Transition Temperature," Appendix A in "An Appraisal of the Properties and Methods of Production of Laminated or Composite Ship Steel Plate," Committee on Ship Steel of the Ship Structure Committee (Nov. 30, 1954).

6. Sims, C. E., Banta, H. M., and Waters, H. L., "Final Progress Report on Metallurgical Quality of Steel Used for Hull Construction," Ship Structure Committee Report, SSC-25 (May 10, 1949).

7. Owen, W. S., Whitmore, D. H., Cohen, M., and Averbach, B. L., "The Relation of the Charpy Impact Properties to the Microstructure of Three Ship Steels," THE WELDING JOURNAL, **36** (11), Research Suppl., 503-s (1957).

8. Tipper, C. F., "The Effect of Direction of Rolling, Direction of Straining, and Ageing on the Mechanical Properties of a Mild Steel Plate," *J. Iron Steel Inst.*, **172**, 143 (1952).

9. Troiano, A. R., and Klinger, L. J., "Directionality of Mechanical Properties in Hot-Worked Steels," THE WELDING JOURNAL, **33** (5), Research Suppl., 209-s (1954).

10. Jatczak, C. F., Girardi, D. J., and Rowland, E. S., "On Banding in Steels," *Trans. Am. Soc. Metals*, **48**, 279 (1956).

RESEARCH NEWS

(*Continued from page 342-s*)

"Operation Deepfreeze" in which the contents of an experimental blast furnace of the U. S. Bureau of Mines were "frozen" during the iron-making process. The experiment is giving science a rare opportunity to examine the full cycle of the transformation of raw materials to iron as it takes place inside a blast furnace.

To chart the step-by-step reduction of ore to iron, U. S. Steel scientists, in cooperation with the Bureau of Mines and technicians from the Linde Co., suddenly quenched the contents of the hot operating furnace with a blast of nitrogen. Thus, the blast-furnace process was halted in midcycle. The loose material in the furnace was removed as 3000 six-inch cube samples during the dismantling of the furnace. The 5200-lb solid mass of coke, metal and slag remaining in the furnace hearth was sampled by core drilling to remove twenty 3-in. diam "core" samples.

While complete analysis of all the samples will require many more months, a number of interesting observations has been made to date. For example, coke was found throughout the slag and metal layers in the hearth, and preliminary analyses of the samples taken from the furnace revealed that the raw materials that are loaded into the top of the furnace in layers move down to the combustion zone in stratified form. Until they reach the smelting area, they remain relatively unchanged in physical appearance.

As a result of further studies, U. S. Steel scientists hope to trace the ore reduction process through the various zones of a blast furnace. They also hope to determine the mechanism of sulfur transfer and chart the path of the sulfur exchange between the iron, the coke and the slag.

Among the other iron-making mysteries which they hope to unravel are the size and location of the fusion zone and the chemical changes in raw materials that take place in the fusion zone.

The opportunity to conduct the freezing experiment came last October when the United States Bureau of Mines decided to move its 34-ft tall experimental blast furnace from the Oakland area of Pittsburgh to Bruceton, Pennsylvania. U. S. Steel's research team of blast-furnace specialists developed the idea in cooperation with the Bureau of Mines, and the Linde Co. supplied nitrogen for the freezing process. This presented an unusual opportunity because the cost of freezing and dismantling a large furnace is prohibitive.

A total of 3,000,000 cu ft of nitrogen was introduced into the furnace over a two-week period. To aid in the cooling process, cold water was poured over the furnace shell. The nitrogen was pumped in through the furnace tuyeres.

High-Temperature Performance

Investigation of Fe-Mn-Cr-N-C System for Heat Resistance and Oxidation Resistance Between 1200 and 2000° F. C. Hsiao and E. J. Dulis, Crucible Steel Company of America for Wright Air Development Center, U. S. Air Force. 158 pages. (Order PB 131563 from OTS, U. S. Department of Commerce, Washington 25, D. C., $4.) Results of this comprehensive study show steels of the austenitic Cr-Mn-C-N type to be outstanding for high-temperature application. The study resulted in establishment of phase boundaries of the base compositions of stable austenitic Cr-Mn-C-N steels and the effects of these elements and of V, W, Mo and Cb on the microstructures. Cr-Mn-C-N base steels were found to possess an excellent combination of strength and ductility at room and high temperatures, although they are not as resistant to oxidation as Cr-Ni steels at comparable Cr levels.

An Investigation of Three Ferritic Steels for High-Temperature Application. A. P. Coldren and J. W. Freeman, University of Michigan for Wright Air Development Center, U. S. Air Force. April 1957. 117 pages. (Order PB 131069 from OTS, U. S. Department of Commerce, Washington 25, D. C., $3.) Relationships were examined between microstructure and high-temperature properties at 700 to 1100° F of a Ni-Cr-Mo steel and two Cr-Mo-V steels. The results correlate properties with microstructure for three temperatures of isothermal transformation in the pearlite region and three in the bainite region. Optimum structures (or treatments) were shown to vary with both the alloy and test conditions. In general, bainitic structures gave best properties. However, for the Cr-Mo-V steels, pearlites formed at relatively low temperatures were often as strong or stronger than the bainites. Tempered martensite was never the strongest structure and most often was the weakest.

Progress Report on the Salt Corrosion of Titanium Alloys at Elevated Temperature and Stress. Titanium Metallurgical Laboratory, Battelle Memorial Institute. November 1957. 57 pages. (Order PB 121637 from OTS, U. S. Department of Commerce, Washington 25, D. C., $1.50.) A type of high-temperature corrosion of titanium alloys by sodium chloride is described which, in the presence of stress, may lead to cracking. Four titanium producers and an aircraft company carried out an extensive research program to determine the time, temperature and stress levels at which this reaction occurs. This report contains results of their study in terms of limiting conditions for stress corrosion in commercial alloys, preventive measures against elevated temperature stress corrosion and the mechanism by which the stress corrosion occurs.

MATERIAL RATING BASED UPON TRUE STRESS-STRAIN PROPERTIES

Authors recommend that, in the future, ratings of materials normally based upon mechanical properties be determined based upon true stress-strain relations

BY JOSEPH MARIN AND M. G. SHARMA

SUMMARY. It is customary for the designer to select a material based upon the nominal or conventional static tensile mechanical properties. However, it is recognized that the properties based upon the nominal stress-strain curve are not correct and that the true stress-strain tension curve should be used. Since the tensile mechanical properties are primarily used for comparative purposes and often not quantitatively, the question arises whether the rating of materials based on the nominal properties is the same as the rating based upon the true properties. If these ratings are found to be the same, then the usual procedure of using the nominal properties for material selections is justified. However, if these two ratings differ, then the true stress-strain properties should be used. In order to answer this question, interpretations were made based upon data for 56 materials. The results show that the material ratings based upon the nominal and true properties are not the same. It is therefore recommended, that in the future, ratings of materials based upon mechanical properties be determined based upon true stress-strain relations.

Introduction

In recent years, true tensile stress-strain diagrams have been used to express more accurately the stress-strain curve. However, little use has been made of the true tensile stress-strain diagram for the purpose of defining the mechanical properties. True stress-strain properties have probably not been used because it has been felt that the nominal or conventional properties are sufficiently accurate for rating the materials. The study reported in this paper shows that the foregoing conclusion is incorrect.

Definition of True Tensile Mechanical Properties

The true tensile stress and strain are based upon the actual cross-sectional area and actual gage length rather than their original values. That is, by definition the true stress is,

Joseph Marin and M. G. Sharma are associated with the Department of Engineering Mechanics at the Pennsylvania State University, University Park, Pa.

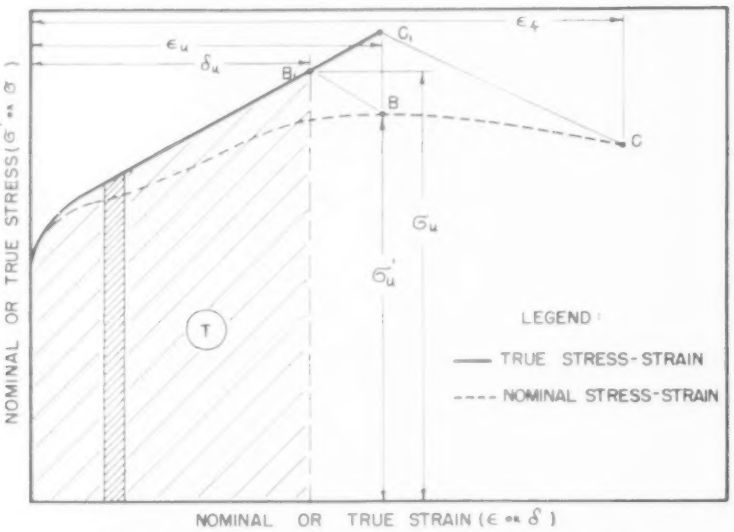


Fig. 1 Nominal and true stress-strain diagrams in tension

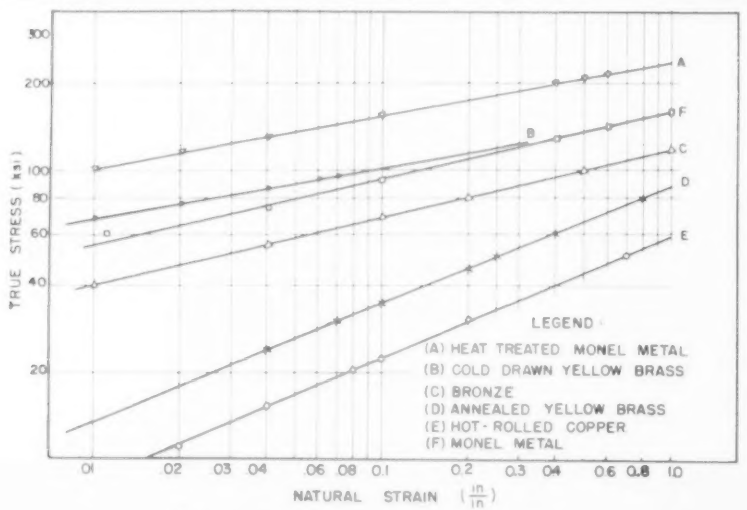


Fig. 2 Log-log true stress-strain relation

Table I—Rating of Materials Based

Material	Heat treatment temperature, °F	Tensile strength, psi			Ductility, %				Toughness, psi				
		Nominal	Grading	True	Grading	Nominal	Grading	True	Grading	Nominal	Grading	True	Grading	Rel.*
SAE 1010 steel		46,500	1	65,900	7	37	35	35	53	18,350	13	17,205	48	5
Tough pitch Copper		46,900	2	68,200	9	15	7	9	23	6,941	3	2,000	8	3
Oxygen free copper		47,500	3	65,550	6	21	16	12	30	9,738	6	4,000	15	3
SAE 1010 steel	1650 F. C.	51,300	4	63,050	4	11	12	20	46	20,770	18	8,940	38	2
Cold drawn Copper		54,000	5	58,200	2	45	17	1	1	22,950	22	5,790	26	1
SAE 1010 steel	1900 A. C.	54,000	6	65,400	5	38	38	19	42	20,230	15	5,139	24	2
SAE 1010 steel	1700 A. C.	54,500	7	66,000	8	38	39	20	47	20,350	17	7,790	36	2
Annealed phosphor bronze C		56,850	8	56,850	1	83	56	2	5	47,186	52	230	1	3
SAE 4615	1600 F. C.	58,000	9	70,800	13	43	45	20	18	24,950	26	5,020	20	2
Ship steel		59,910	10	68,600	10	26	22	23	51	15,577	11	13,829	43	5
SAE 1020 steel		60,000	11	70,500	11	37	36	33	52	22,200	20	20,760	52	5
Ambrac 3420		61,200	12	61,200	3	25	20	2	6	15,178	9	770	5	3
SAE 4615	1650 A. C.	61,500	13	73,200	15	41	41	17	41	25,200	27	6,120	29	2
14 ST-4		61,500	14	74,400	17	22	18	19	43	13,530	7	11,735	40	5
Tobin bronze 3026		62,000	15	76,500	19	47	48	21	50	29,016	41	4,650	19	3
SAE 4615	1650 Mica	63,000	16	76,000	18	42	44	19	44	26,450	50	5,020	21	2
Annealed steel #4		66,500	17	84,500	22	71	51	10	28	46,883	51	12,730	41	1
Annealed steel #1		67,000	18	86,500	24	57	49	8	21	38,190	50	14,350	45	1
Cupro nickel 3421		67,300	19	84,900	23	23	19	20	49	15,344	10	9,135	39	3
24 ST		68,000	20	77,500	20	14	5	12	31	9,520	5	8,561	37	5
Annealed brass 65/35		68,800	21	70,600	12	21	15	3	10	14,104	8	320	3	3
12% Cr-0.08% C Steel	1550 F. C.	68,800	22	83,250	21	43	46	19	45	29,200	42	22,300	54	2
14 ST-6		69,100	23	72,250	14	9	2	6	13	6,249	2	4,411	15	6
Cold drawn brass 1/2 hard		69,500	24	86,500	25	37	37	6	14	25,715	28	13,890	44	3
Annealed phosp. bronze A		71,800	25	73,500	16	73	52	2	7	36,062	48	400	4	3
SAE 6140		74,300	26	87,200	26	36	34	16	40	26,750	31	15,170	46	2
25% C steel	Hot rolled	78,000	27	92,040	29	38	40	7	17	29,640	44	23,500	55	4
95% C steel	Annealed	78,500	28	95,500	30	41	43	6	15	32,185	45	13,650	42	1
SAE 3135	1425 (40°F/hr) to 1200 AC	84,500	29	101,700	34	33	32	16	38	37,900	49	5,050	22	2
SAE 6145	1380 (40°F/hr) to 1200 AC	85,500	30	100,500	33	34	33	16	39	28,900	40	7,400	35	2
Annealed phosphor brass D		87,400	31	87,400	27	76	53	1	2	48,169	53	230	2	3

$$\sigma = \frac{P}{A} \qquad (1)$$

where P = the load and A = the cross-sectional area corresponding to the load P.

The true strain is,

$$\delta = \int_{L_o}^{L} \frac{dL}{L} = \log_e\left(\frac{L}{L_o}\right) \qquad (2)$$

where L_o = the original gage length and L = the gage length corresponding to the load P.

The nominal stress and strain are respectively

$$\sigma' = \frac{P}{A_o} \text{ and } \epsilon = \frac{L - L_o}{L_o}$$

Figure 1 shows plots of both the true and nominal stress-strain diagrams. The elastic mechanical properties including yield strength, stiffness (modulus of elasticity) and resilience (modulus of elastic resilience) are not influenced by considering the true stress and strain, since in the elastic range the true and nominal values of the stress and strains are essentially equal. The "plastic" mechanical properties based upon the nominal stress and strain are usually expressed by the nominal ultimate strength (measured by the nominal ultimate stress = σ_u') nominal ductility (measured by the percentage elongation at fracture = $100\,\epsilon_f$) and the toughness (measured by the toughness index number = $\epsilon_f \times \sigma_u'$).

The "plastic" mechanical properties based upon the true stress-strain relations can be defined as the true ultimate strength (as measured by the true ultimate stress = σ_u); the true ductility (as measured by the true percentage elongation at the ultimate load = $D = 100\delta_u$) and the true toughness (as measured by the work done on a unit volume up to the ultimate stress). Appendix I shows that the values of the true properties in terms of the nominal mechanical properties are related by the following equations,

$$\sigma_u = \sigma_u'(1 + \epsilon_u) \qquad (3)$$

$$D = [\log_e(1 + \epsilon_u)]100 \qquad (4)$$

$$T = \frac{Kn^{n+1}}{(n+1)} \qquad (5)$$

where:

n = the strain-hardening exponent.

K = the strength coefficient.

Equation 5 is based upon the assumption that the true plastic stress-strain relation can be expressed by $\sigma = K(\delta)^n$.

Material	Heat treatment temperature, °F	Tensile strength, psi			Ductility, %				Toughness, psi				Ref.*
		Nominal	Grading	True	Grading	Nominal	Grading	True	Grading	Nominal	Grading	True	Grading	
SAE 4635	1550 Mica	87,500	32	97,100	34	26	23	10	27	22,750	21	6,410	30	2
18% Cr-8% Ni 0.05% C steel	1900 WQ	87,500	33	145,100	50	82	55	51	56	71,250	55	21,450	53	2
SAE 3135	1550 Mica	88,000	34	99,100	32	31	30	14	35	26,820	34	6,070	27	2
75 ST-6		88,000	35	92,000	28	10	3	9	24	8,800	4	6,995	34	5
18% Cr-8% Ni 0.06% C steel	1900 WQ	90,000	36	136,000	47	69	50	41	54	62,500	51	18,350	51	2
SAE 3140	1425 (40°F/hr) to 1200 AC	90,800	37	105,600	35	30	29	15	37	26,770	33	6,505	31	2
18% Cr-8% Ni 0.06% C steel	1900 WQ	98,300	38	161,000	55	79	54	50	55	77,600	56	28,518	56	2
SAE 1050	1650 AC 1550 WQ 1600 Mica	99,000	39	142,300	36	27	24	14	39	27,200	35	17,590	49	2
SAE 1050	1650 AC 1600 Mica	99,500	40	144,000	37	28	26	13	32	26,360	29	17,590	50	2
SAE 2345	1550 Mica	101,000	41	145,000	39	28	27	13	33	28,250	38	6,810	32	2
SAE 4140	1550 OQ 1160 AC	101,600	42	144,200	38	28	28	9	25	29,300	43	3,345	13	2
SAE 1040		105,000	43	122,000	33	31	31	2	8	32,550	47	15,380	47	1
SAE 1045	1520 WQ 1120 AC	105,600	44	116,000	30	27	25	10	29	28,500	39	3,345	12	2
Everdur 1010		106,100	45	121,000	32	15	6	13	34	16,386	12	1,453	6	3
SAE 2335	2100 AC	109,100	46	119,000	31	18	10	9	26	19,900	14	4,460	18	2
SAE 1045		113,000	47	122,000	14	18	14	1	3	20,340	16	5,650	25	1
SAE 4140	1550 OQ 1250 AC	113,800	48	122,900	45	25	21	8	22	27,850	36	6,925	33	2
SAE 4340	1550 OQ 1140 AC	127,300	49	136,200	18	21	17	7	18	26,750	32	6,100	28	2
Nickel chrom molyb. steel		130,000	50	132,700	16	17	8	2	9	22,100	19	2,583	11	5
SAE 3145	1520 WQ 1040 AC	131,300	51	143,800	19	18	12	7	19	24,180	24	3,785	14	2
SAE 4345	1550 OQ 1140 AC	141,100	52	151,000	51	20	13	7	20	28,230	37	5,050	23	2
SAE 1330	1550 OQ 900 AC	149,300	53	158,300	52	17	9	6	16	24,630	25	1,619	7	2
18% Cr-6.08% steel	1750 WQ 800 AC	169,800	54	179,000	54	20	14	5	11	32,250	46	2,185	9	2
SAE 6145	1700 FC to 1500, O 1000 AC	185,900	55	195,000	55	13	4	5	12	23,220	23	2,375	10	2
Beryllium copper		213,000	56	238,000	56	3	1	1	4	5,364	1	4,200	17	3

* Reference at the end of the paper.

The ultimate load rather than the fracture load is used for defining the true strength, ductility and toughness, since the part of the stress-strain curve beyond the ultimate or instability load does not represent a uniaxial state of stress. Furthermore, from the designer's point of view, the material cannot resist any further increase in load beyond the ultimate stress and, therefore, this stress represents the failure stress.

Material Ratings Based on Nominal and True Mechanical Properties

To compare materials rating based upon the nominal and true stress-strain curves, the literature was searched in order to find complete stress-strain data. For this purpose, the results obtained by several investigators[1-5] on simple tension tests were used. Particularly important among these may be mentioned MacGregor[1] and Janitzky and Baeyertz.[2] The materials tested in these investigations are listed in Table 1, in order of their nominal ultimate strengths. For each property the grading of the material is identified by the number accompanying each property value.

Based upon the data given in References 1 to 5, the nominal ultimate strength $= \sigma_u'$, ductility $= 100\ \epsilon_f$ and toughness $= \sigma_u' \epsilon_f$ and their true values are determined. The values of these properties and their ratings are given in Table 1.

The true ultimate strength and true ductility can be determined from eqs 3 and 4, since σ_u' and ϵ_u are known. The values of these properties and their ratings are given in Table 1.

To determine the true toughness, the area under the true stress-strain diagram up to the true ultimate load could be used. However, such a procedure is time consuming and the value defined by eq 5 will therefore be used. In order to determine the toughness by eq 5, values of K and n must be determined. For this purpose, the true stress-strain curves were plotted on log-log paper as illustrated in Fig. 2. Assuming that straight lines in Fig. 2 can be used to represent the true stress-strain relations, then values of K and n in $\sigma = K(\delta)^n$ can be determined. With K and n known, by eq 5 and Fig. 3, the true toughness values can be calculated. These true toughness values are listed in Table 1, for the various materials in order of their magnitudes.

An examination of Table 1 shows that

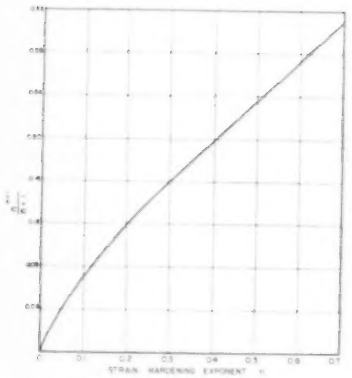


Fig. 3 Determination of value $\frac{n^n+1}{n+1}$

the same order of magnitudes does not apply for both the nominal and true properties. In other words, material ratings based upon the nominal properties can be incorrect.

Conclusion

This paper gives the results of a study on material ratings based upon the nominal and true mechanical properties in tension. The results show that these two ratings are not the same. The significance of this conclusion is that the usually determined nominal properties may lead to the wrong material selection.

Acknowledgment

The sponsorship and financial assistance of the Welding Research Council in making possible this study is gratefully acknowledged. The technical assistance and guidance provided by the Pressure Vessel Research Committee and particularly Mr. W. R. Burrows are also greatly appreciated.

References

1. MacGregor, C. W., "Tension Test," *Proc. ASTM*, **40**, 527 (1940).
2. Janitzky, E. J., and Baeyertz, M., "Interrelation Between Stress and Strain in the Tension Tests," *Trans. Am. Soc. Metals*, **28**, 714 (1940).
3. Smith, C. S., and VonWagner, R. W., "Tensile Properties of Some Copper Alloys," *Proc. ASTM*, **41**, 825 (1941).
4. Parker, E. R., Davis, H. E., and Flannigan, A. E., "On the Study of Tension Test," *Proc. ASTM*, **46**, 1159 (1946).
5. Griffis, Levan, and Morikawa, G. K., "Behavior of Steel Under Conditions of Multiaxial Stress," OSRD Report No. 5346.
Lessels, J. M., and MacGregor, C. W., "Certain Phases of Combined Stress Problem," *Proc. of the V International Congress on Applied Mechanics*, 201–206 (1938).
Davis, H. E. and Troxell, G. E., "Behavior of Steel Under Conditions of Multiaxial Stresses," OSRD Report No. 4553.
Marin, Joseph, and Hu, L. W., "Plastic Stress-Strain Relations for Biaxial Tension and Variable Stress Ratios," *Proc. ASTM*, **52**, 1098 (1952).
Marin, Joseph, Hu, L. W., and Hamburg, J. F., "Plastic Stress-Strain Relations of Alcoa 14ST-6 for Variable Biaxial Stress Ratios," *Proc. Am. Soc. Metals*, **45**, 686–709 (1953).
Marin, Joseph, Ulrich, R. H., and Hughes, W. F., "Plastic Stress-Strain Relations for 75 ST-6 Aluminum Alloy Subjected to Biaxial Stresses," NACA Tech. Note 2425.
Marin, Joseph, Faupel, J. H., Dutton, V. L., and Bressman, M. W., "Biaxial Plastic Stress-Strain Relations for 24 ST Aluminum Alloy," NACA Tech. Note 1536 (1948).

APPENDIX

Determination of True Mechanical Properties

This appendix gives the derivation of the true mechanical properties in terms of the nominal stress σ_n' and strain ϵ_n as expressed by eqs 3, 4 and 5.

True Ultimate Stress

To define the true stress in terms of nominal quantities, it will be assumed that there is no volume change in the plastic range.* Then,

$$A_n L_n = AL$$

or

$$A = A_n \frac{L_n}{L} \qquad (a)$$

But

$$\epsilon = \frac{\Delta L}{L_n} = \frac{L - L_n}{L_n} = \frac{L}{L_n} - 1$$

and

$$L/L_n = (1 + \epsilon) \qquad (b)$$

From eqs (*a*) and (*b*)

$$A = \left(\frac{A_n}{1 + \epsilon}\right) \qquad (c)$$

Since the true stress is $\sigma = P/A$ then:

$$\sigma = \frac{P}{A} = \frac{P}{A_n}(1 + \epsilon)$$

or

$$\sigma = \sigma_n'(1 + \epsilon) \qquad (d)$$

Applying eq (*d*) to the ultimate stress,

$$\sigma_u = \sigma_{nu}'(1 + \epsilon_u) \qquad (3)$$

That is, eq 3 defines the true ultimate stress σ_u in terms of the nominal ultimate stress σ_{nu}' and the nominal strain ϵ_u at the ultimate load.

True Ductility

By definition the true strain is

$$\delta = \int_{L_n}^{L} \frac{dL}{L} = \log_e\left(\frac{L}{L_n}\right) \qquad (e)$$

* Tests show that this is a good approximation

Placing the value of L/L_n from eq (*b*) in (*e*)

$$\delta = \log_e(1 + \epsilon) \qquad (f)$$

Applying eq (*f*) to the ultimate load, the true ultimate strain or true strain at the ultimate load is,

$$\delta_u = \log_e(1 + \epsilon_u) \qquad (g)$$

where ϵ_u is the nominal strain at the ultimate load.

The true ductility will be defined as the percentage true strain at the ultimate load. That is by

$$D = 100\delta_u = 100 \log_e(1 + \epsilon_u) \qquad (4)$$

Equation 4 expresses the true ductility in terms of the known nominal strain ϵ_u.

True Toughness

In place of determining the true toughness by the tedious method of evaluating the area under the true stress-strain, an equation defining the true toughness will be obtained. This equation for the toughness will represent an approximation based upon the assumption that the true stress-plastic strain relation is

$$\sigma = K(\delta)^n \qquad (h)$$

Noting that $\sigma = P/A$

$$P = AK(\delta)^n \qquad (i)$$

From eqs (*e*) and (*f*)

$$A = A_n(1 + \epsilon) = A_n e^{\delta} = A_n e^{\delta} \qquad (j)$$

Then by eqs (*i*) and (*j*)

$$P = KA_n e^{\delta}\delta^n \qquad (k)$$

The maximum load is obtained by placing $dP = 0$, or by eq (*k*)

$$dP = KA_n(e^{\delta} n\delta^{n-1} + \delta^n e^{\delta})d\delta = 0 \qquad (l)$$

or

$$\delta_u = n \qquad (l)$$

The true toughness is defined by:

$$T = \int_0^{\delta_u} \sigma d\delta = \int_0^{\delta_u} K\delta^n d\delta$$

or

$$T = \frac{K\delta^{n+1}}{(n+1)} \qquad (m)$$

From eqs (*l*) and (*m*)

$$T = \frac{Kn^{n+1}}{(n+1)} \qquad (5)$$

Equation 5 expresses the true toughness in terms of the strength coefficient K and strain hardening exponent n.

CURRENT WELDING RESEARCH PROBLEMS

This list was made to inform Welding Research Council project committees and university research workers of some of the more important research problems facing industry. These suggestions are considered important because they have come largely from engineers, scientists and executives of American industry and government agencies

General Comments

Approximately every two years the Welding Research Council asks Industry for their suggestions and opinions on problems which might be undertaken by the project committees of the Council and its University Research Committee.

Welding is of great importance now because it has become firmly established as an accepted method of fabrication with a very wide range of application. Welding is used to join hundreds of different commercial alloys in thousands of different shapes. Plain carbon, low-alloy and stainless steels as well as a great many nonferrous alloys such as aluminum, nickel, copper, titanium and zirconium are welded very widely. Many of the new high-temperature superalloys are fabricated into useful components by welding. Sheets of all thicknesses ranging from a few mils to over 20-in. thickness are joined. Actually, some products could not even be made without the use of welding; for example, guided missiles, nuclear power plants, jet aircraft, chemical processing equipment and thousands of others. Welding processes are of great economic importance because they are one of the important tools available to the engineer in his efforts to reduce production and fabrication costs.

The welding industry has many interesting and challenging problems because it embraces practically every branch of the basic sciences and engineering. Some of these problems are so broad and complex that their solution requires the coordinated effort and knowledge of experts in many branches of science. Many welding problems are suitable for university research projects on both undergraduate and graduate levels. Some of the problems which are not suitable for universities can be handled by and would be of interest to industrial research institutes or foundations.

Some of these welding research problems require substantial investment of equipment, time and money, but many of them can be subdivided or enlarged to conform to the limitations of time and equipment of any research worker for short or long periods of time.

The Welding Research Council at 29 W. 39th St., New York 18, N. Y., welcomes offers of university professors to carry out an investigation of any of the problems listed here. As a basis of discussion with the Welding Research Council, it would be of great help if the professors would outline their proposed program and submit it to the Council for preliminary evaluation and comments. It is recommended that plans be made well before the time at which the research is scheduled to start because of the time required for delivery of materials and equipment and for appropriation of necessary funds. A comprehensive and thorough investigation of a problem frequently requires a continuity of effort such as a series of studies and investigations, properly coordinated by the professor in charge. Progress reports of each professor and his co-author are published. This helps to develop the interest of representatives of industry and also to give recognition to the professor and his university.

The professors at those universities which have been affiliated with the University Research Committee of the Welding Research Council for many years appreciate the usefulness of such a list of suggested welding research problems and the advantages of affiliation with the Committee. To those who are not familiar with the sound opportunities afforded to research workers by affiliation with the Committee, one of the more important activities would be of interest and may be described.

A conference of university research professors is held each year during the Annual AWS Welding Show. The Welding Research Council makes funds available to help pay for transportation expenses of professors who attend, with a limit of $50 to any one professor or research worker. This helps to provide an opportunity for the university research worker to discuss his problems with representatives of industry and with other research workers in many fields of activity.

Through close association with the AWS, opportunity is provided for the presentation of results of a research project before the SOCIETY at the Annual Spring

Meeting. An opportunity is provided for its publication in the Welding Research Supplement of THE WELDING JOURNAL even though the paper may not be presented at the Annual Meeting. This Supplement accounts for about half of the technical pages of THE WELDING JOURNAL, which exerts great influence in the welding industry because it reaches scientific workers throughout the world.

Suggested Programs

In a similar compilation of research problems prepared three years ago and published in the June 1955 issue of the Welding Research Supplement, the suggestions received at that time were listed under eight headings. This year the list has been expanded to 18 with a total of about one hundred problems. These suggested welding research problems are presented as follows.

Group I—Stainless-Steel and High-Alloy Welds

1. Determine the causes of hot cracking in welded Type 347 stainless-steel castings and forgings. It might be of value to study the effect of ferrite on the nucleation and growth and resulting grain size of austenite. Hot cracking in wrought Type 347 stainless steel in the base metal next to the weld requires study also. The effects of Sn, P, S, Pb, N and C along with grain size and the advantage of vacuum melting and pouring require investigation.

2. The effects of preheating and postheating treatment, as well as low-temperature cooling, of stainless steels should be studied. It appears that various types of stainless steel may require different heat treatments to avoid hot cracking in the weld metal or base metal next to the weld and to improve corrosion resistance and low-temperature impact strength.

3. The effects of dilution when welding stainless steels with dissimilar welding electrodes should be investigated. Buttering with Inconel Type 309 or Type 310 stainless steel should be compared with direct welding methods using Inconel electrode or wire, with or without combinations of other electrodes. The effect of welding processes and techniques should also be included.

4. Investigate the basic factors which influence hot cracking of both ferritic and austenitic weld metals. This should include a study of low-melting intergranular phases, and their effect on the nature, origin and path of hot cracking, and a survey of atomic radii, melting point, crystal structure and diffusion rates of solute elements and compounds in relation to the matrix.

5. Determine the causes of cracking and welding difficulties experienced in the welding of various wrought high-alloy materials, to themselves and to various stainless steels. The various types of welding processes and weld-rod compositions such as nickel-base alloys and others, should be examined as joining materials.

6. Determine the causes of cracking and the effects of dilution when welding the various high-alloy cast materials containing aluminum, titanium and boron to the various stainless steels, using dissimilar welding-rod compositions such as the nickel-base types.

(*a*) Examine the effect of aluminum, titanium and boron composition levels and weld cracking incurred to determine the maximum boron levels acceptable for a weldment.

Group II—Carbon and Low-Alloy Steel Welds

1. A study of weld metal produced under a high-hydrogen atmosphere compared with that produced using low-hydrogen welding processes such as low-hydrogen coated electrodes, inert-gas-shielded welding processes and the submerged-arc welding process.

2. A study of the distribution of hydrogen in ferrite, bainite, martensite and austenite, because no single theory has been universally accepted.

3. A study of diffusible and nondiffusible hydrogen and their relation to cracking or reduced ductility.

4. A study of diffusible and nondiffusible nitrogen and their possible relation to cracking or reduced ductility.

5. Determine how electrodes (high alloy and stainless included) should be processed, handled and stored, in order to avoid troubles arising from possible moisture and hydrogen pickup.

6. Investigate methods of restoring electrode coatings after improper handling or storage.

7. Determine the relationship between amount and type of distribution of iron sulfide on hot cracking.

8. Determine the chemical and physical reasons for reduction of hot cracking in the welding of high-sulfur steels when low-hydrogen electrodes are used. The effect of carbon, manganese silicon, hydrogen, phosphorous, nitrogen and intergranular phases might all play some part in this phenomenon.

9. Investigation of the role of hydrogen and nitrogen in the formation of porosity.

10. Develop fluxes and electrodes for submerged-arc welding of heavy sections of low-alloy high-strength steels such as T-1, HY80, Cr-Mo, etc.

11. Investigate the effect of alloy additions to electrodes for the CO_2-shielded arc-welding process.

To date, a great amount of work has been done with this process on the welding of low-carbon steels and satisfactory electrodes have been developed for this purpose. However, severe cracking problems have been encountered using the CO_2 process when welding medium-carbon steels (above 0.35% C) even with preheat. It is thought alloy additions to the electrode may help on this problem.

Group III—Transition from Ductile to Brittle Behavior in Steels

1. Further study of methods for correlating the behavior of small-scale test specimens with the service performance of larger sections. More exact information must be obtained on service conditions.

2. Investigation of the effect of heat treatment, composition and structure of newer high-strength low-alloy steels.

3. Investigate the effect of various degrees of restrain in thick sections and the effect of fabricating processes other than welding.

(*a*) Influence of prestrain on the initiation of brittle fracture.

(*b*) Influence of residual stresses on the initiation of brittle fracture.

4. Further study of the effect of temperature on properties of weld.

5. Further study of the effect of temperature on plastic deformation—for example, the curves of hardness, strain, ductility or impact resistance are characterized by discontinuities and maxima and minima which require explanations. The location of these peaks and valleys is affected by chemical composition, steelmaking practice, heat treatment and fabrication operations. These require additional study.

6. Determination of theories to explain the origin of microscopic fractures that lead to low-temperature brittleness. This information would help to outline practical steps to use for producing optimum properties in commercially produced materials.

7. Investigation of the factors which influence the properties of aluminum-killed steels and determination of practical steps which can be used to improve mechanical properties of commercially hot-rolled material. Normally, aluminum-killed steel in the as-rolled condition is not as ductile and shock resistant as normalized material. (Normalizing is said to precipitate all the aluminum nitride from the austenite—see *Welding Research Abroad*, April 1958, page 2).

8. Further study of transition temperatures of various welded materials; for example, comparing rimmed steel with fully killed steel at several different carbon levels. This study should include the comparison of low-hydrogen electrodes of the lime type and titania type with the usual cellulose-type coating.

Group IV—Preheating Vs. Postheating

1. Determine quantitative values of preheating required for different thicknesses of more commonly welded steels.

2. Investigation of the effect of preheating and heating and cooling rates on distortion and cracking.

3. The effect of preheating on notch toughness of welds.

4. Comparison of localized with general preheating and postheating.

5. Determination of the quantitative relations between notch toughness and the time and temperature of postheating.

6. A study of the relative importance of stress relieving and tempering on notch toughness and other mechanical properties of welded pressure-vessel steels.

7. Additional study of strain aging effects during postheating on the properties of both weld and base metals.

Group V—Corrosion

1. Determination of corrosion theories and practical importance for reducing or eliminating the various types of corrosion encountered, . .for example, stress corrosion cracking, pitting corrosion, general corrosion, corrosion fatigue and pickup of hydrogen because of corrosion. This is a broad and important subject for investigation.

Group VI—Nondestructive Tests

1. Development of more economical and more rapid means of nondestructive testing of welded components would be of substantial help in reducing production costs in many industries. Further improvement in existing radiographic methods and techniques would be worth while, using X-ray machines or radioactive isotopes.

2. A study of means for improving filmless radiographic techniques.

3. Further study of the magnetic particle process.

4. Improvement of ultrasonic testing, procedures and equipment.

5. Improvement of the penetration oil testing method, equipment and materials. The sensitivity, surface preparation and exposure-time parameters should be investigated and standardized for the various penetrants.

Group VII—Anisotropy

1. Development of more information on the effect of temper embrittlement, hydrogen embrittlement and prestraining on directionality is needed.

2. Investigation of the effect of welding on directionality.

3. A study of the effect of steelmaking practice on directionality. These problems apply to other metals also such as zirconium, titanium, magnesium, etc., and their alloys.

Group VIII—Aircraft Problems

Welding—General

1. Evaluate the mechanical (including fatigue at subzero, room and elevated temperatures) and metallurgical properties of welds (fusion, resistance, flash and pressure), in air hardening AISI 400 series corrosion and heat-resistant steels such as AISI 410, AISI 422, and in hot worked die-tool steels.

2. Investigation of the effect of surface films in the spot, seam, flash, pressure and ultrasonic welding of precipitation hardenable stainless steels, superalloys, die-tool steels and molybdenum.

3. Investigation of influence of residual welding stresses (developed by fusion, spot and seam welds) on the fatigue life of materials suitable for aircraft applications.

Fusion Welding

4. Investigation of the effect of laminated-sheet thicknesses (multiple sheets) on the mechanical and metallurgical properties of fusion welds in alloys suitable for aircraft application.

5. Evaluation of mechanical properties of arc welds in misaligned sheet-metal butt joints.

6. Welding of precipitation hardening alloys for high temperature service.

7. Investigation of notch sensitivity of fusion welds in titanium and titanium alloys.

8. Develop and build spot-weld equipment incorporating hydrostatic pressure to be applied during the process to increase fatigue resistance of spot welds as shown by Dr. G. Welter of Ecole Polytechnique, Montreal.

Flash and Pressure Welding

9. Evaluate the mechanical (including fatigue at subzero, room and elevated temperatures) and metallurgical properties of flash and pressure welds in titanium alloys such as 6Al — 4V, 7Al — 4Mo, etc.

Brazed and Welded Sandwich Structure

10. Develop brazing techniques other than furnace methods for producing brazed honeycomb-sandwich structures. Methods to be studied would include: (*a*) electric blanket, (*b*) quartz lamps, (*c*) radiant gas, etc.

11. Evaluate welded as well as brazed sandwich construction other than honeycomb, such as waffle, double skin and corrugations. 90-deg flange core, etc. Consideration to be given to elevated-temperature properties and adaptability to airframe sections such as fuselage, wing, etc., having both single and double contour.

Skins and Coatings

12. Investigate various wear-resistant coatings applied by flame spray process and develop standard requirements.

13. Investigate the effectiveness of flame-sprayed aluminum oxide and other refractory coatings for thermal-barrier applications.

Group IX—Problems in Welded Nuclear-Power Components

1. Stainless and alloy surfacing of steel pressure vessels should be studied. At the present time the inside of most of the pressure vessels for atomic reactors is being clad with stainless steel using the submerged-arc-welding process, or by utilizing roll-clad plate. It would be worth while to do development work to prove the advantages of cladding these pressure vessels with the inert-gas metal-arc process using auxiliary filler-metal addition because this procedure would reduce the dilution of the stainless cladding with the base metal, maintain chemical composition and give a good bond.

2. At the present time most of the Zircaloy that is welded for use in nuclear components is welded in special shielding chambers which are evacuated to a very low pressure of 0.03 micron and then back-flushed with high-purity inert gas before welding. This evacuation requires quite a long time. However, it may not be necessary to evacuate the welding chamber to such a very low pressure before welding, but enough work has not been done to prove this. It would be worth while to determine if a less severe vacuum could be used and to determine the effects of atmosphere purity on the hot-water corrosion resistance of welded Zircaloy.

3. Welding tests have shown that it is difficult to obtain good weld penetration in vacuum-melted Zircaloy when it is much thicker than $\frac{1}{8}$ in. Results of further tests would be useful for assisting in the fabrication of nuclear-reactor components made of Zircaloy, particularly since vacuum-melted Zircaloy is now used in preference to inert-gas-melted Zircaloy for many nuclear-reactor core components.

4. Brazing would be preferable to welding for some joint designs in nuclear-reactor components. At the present time, brazing alloys developed for joining Zircaloy do not have good corrosion resistance in high-temperature water. However, it would be worth while trying to develop one because design flexibility would be increased if satisfactory brazing alloys and procedures could be developed.

5. Hard-surfacing alloys useful for eliminating erosive corrosion in nuclear-reactor cores should be developed. Alloys that have low cobalt and boron contents are required in order to minimize the neutron absorption and accessibility problems. Many of the normal commercial hard-surfacing alloys cannot be used because they are high in cobalt or boron.

6. The use of steel castings for nuclear pressure-vessel domes would reduce their cost substantially, if it could be proved that steel castings would be suitable for use in welded pressure vessels of this type. An investigation of the quality and general weldability of high-strength steel castings would be worth while.

7. The use of high-strength titanium alloys would help to reduce the weight of portable nuclear-power plants such as those being contemplated for high-speed naval and merchant ships. However, additional work would be required to prove the feasibility and economies of using welded titanium components for such applications.

8. Investigation of the effect of chemical inhomogeneity and laminations on the weldability of thick steel plate.

9. Investigation of the effect of surface conditions on the properties of thick steel plate. Correlate steel composition and tendency to form surface defects, e.g., the effect of alloying additions of Mo, Mn, Si, Ti, Al, V, Zr, S, P, Cr, Ni, C, etc.

10. Study the effect of H, N and O on thick steel sections, with particular reference to flaking, cracking or reduction in ductility.

11. Effects of irradiation on welded and brazed joints in stainless steels, carbon and low-alloy steels, Zircaloy, etc.

12. A study of the serious anisotropy of wrought Zircaloy.

Group X—Structural

1. Study the feasibility of using $\frac{5}{16}$-in. diam electrodes for horizontal fillet welding and for the root pass

of fillet welds made in the flat position. The AWS Building & Bridge Codes prohibit $\frac{5}{32}$-in. electrodes for the above use; the Rules of the American Bureau of Shipping do not.

2. Determine the validity of: (*a*) AWS Bridge Code paragraph 506(e) "Neither the depth of fusion nor the total width of fusion at any point in a single weld shall exceed the width of the face of the weld or pass." (*b*) AWS Bridge Code paragraph 506(f) ". . . The maximum welding current to be used for any pass that has fusion to both faces of a welding groove shall be 600 amp, except that a pass at the surface of the base metal may be made using a higher current."

3. Fatigue of welded joints subjected to random fluctuating stresses.

4. Fatigue stresses in compression members of structural steel.

5. Further study of the effect of residual stresses on service performance of welded-steel structures.

6. A quantitative determination of the distortion resulting when using various welding techniques and processes. . . for example, the cumulative effect of many stringer beads, the relative effect of large vs. small passes, the effect of high welding speed vs. low welding speed, etc.

7. Determine the practicability of producing new types of rolled and formed sections that are especially adapted to welded construction. This will be of increasing importance with time.

8. A study of the effect of temperature and size of heated areas used in localized heating to remove buckles from plating and structural shapes.

Group XI—Pressure Vessels and Piping

1. The diffusion rates of hydrogen through carbon and alloy steels exposed to temperatures of 500° F and higher and pressures of 100 psi and higher.

2. Creep buckling of plates of steels ordinarily used in pressure-vessel construction.

3. Pressure-vessel heads of all shapes, including thick flat, with multiple penetrations. There is an increasing need for vessels of this type, especially for nuclear service, but scanty data. Need stress-strain data, backed by actual measurements.

4. Determination of the solubility and diffusion rate of nitrogen in relation to composition, temperature and pressure of ferritic and austenitic weld metals.

5. Determination of the solubility and diffusion rate of oxygen in ferritic and austenitic weld metals as affected by composition, temperature and pressure.

6. A further study of the welding of low quality, more economical steels containing segrations and inclusions, particularly using the submerged-arc welding process. The effect of size, type and distribution of segregated phases should be studied.

Group XII—Ship Welding

1. To develop more economical methods or electrodes for welding higher-strength steels without the use of extensive preheating which is so costly and difficult for large structures, such as ship hulls.

Group XIII—Resistance Welding

1. Spring Follow-Up. Information is desired on the value and result of spring follow-up for spot and projection welding.

2. Ring-Type Projections. Very little information is available on this subject. Since joints are being made with this type of projection, more work is required on formed-ring, machined-ring and annular-ring projections.

3. Improved instrumentation is required for resistance welding to measure the three-phase secondary current, voltage and power output more accurately.

4. A further study of equipment and procedures for making wide seam welds. This might offer advantages in producing clad metals, for example.

5. Investigate the use of heavier resistance-welding schedules. It is believed that the resistance-welding schedules recommended by the American Welding Society utilize low electrode force and welding current in favor of the use of lighter equipment. It has been found that the use of an electrode force approximately 50% greater than that specified by the American Welding Society schedules, with a corresponding increase in welding current, compensates for normal production variations in welding conditions. It has been demonstrated on production applications that the use of the heavier schedules results in more consistent welding results. The optimum welding current and time should be determined for the heavier electrode force used and the consistency of weld nugget diameter and weld strength should be determined. Indention, metal expulsion and electrode life should also be evaluated and compared to the present American Welding Society recommended schedules.

Group XIV—Study of Welding Arcs

1. Investigation of arc stability and methods for stabilizing arcs. It would be worth while to study ionization potentials of the arc atmosphere, voltage gradients in the arc column, the effects of current density, electrode materials and shielding atmosphere.

2. Arc heating, when using a rapidly moving arc, for example, up to several thousand inches per minute.

3. Investigate the influence of metal conditions upon the welding arc, for example, the melting and boiling points of the metal, the thermal conductivity, the heat of vaporization, the temperatures of the base metal and electrode.

4. An investigation of the ionization of the arc and of the nature of the ions contributing to conduction in various types of arcs would be valuable. Some of the problems would be:

(*a*) The source of the charge carriers, for example, electrode, base metal, coating or flux or gas shield.

(*b*) Influence of the shield on the discharge.

(*c*) The nature of arcs using different metal electrodes.

5. A study of the electrical conductivity, surface tension and viscosity of welding slags up to arc tem-

peratures, particularly slags used for submerged-arc welding.

6. An investigation of the slag-metal reactions in submerged-arc welding of stainless steel and high-temperature alloys. This work would help to determine the effect of flux composition upon the efficiency of alloy transfer across the arc.

Group XV—Arc Cutting

1. The inert-gas arc-cutting process should be studied further to determine the effect of various types of shielding gases and nozzle shapes on cutting rates and economy.

Group XVI—Ultrasonic Welding

1. The ultrasonic welding process for both spot and seam welding should be investigated more fully.

Group XVII—Electro-Percussive Welding

1. This process is particularly useful for joining small sections to large sections and requires additional study.

Group XVIII—Dissimilar-Metal Welds

1. Additional investigation of welding procedures for joining austenitic stainless steels such as 301 and 347 to low-alloy steels such as 16 Cr-8 Ni-2 Mo, A302-B, HY-65, etc.

2. Joining of Zircaloy to stainless steel.

3. Fatigue study of welds joining austenitic to ferritic steels under thermal cycling with and without high pressure.

Welding Research Council Bulletin No. 40

by Joseph Marin and M. G. Sharma

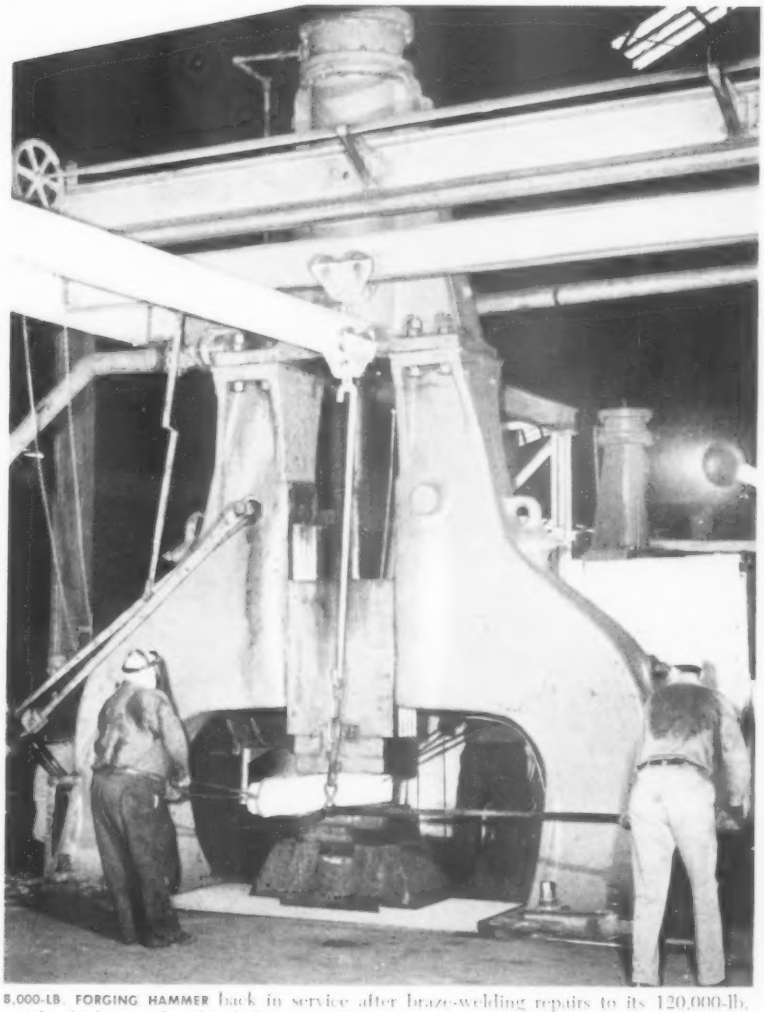
Design of a Thin-Walled Cylindrical Pressure Vessel Based Upon the Plastic Range and Considering Anisotrophy

Various methods and theories of failure have been used to determine the wall thickness of pressure vessels. These theories and methods are based upon simple tensile yield strength or ultimate strength and have been thoroughly reviewed by W. R. Burrows. In using simple tensile yield or ultimate strength as a basis for failure, no consideration is given to the plastic deformation properties of the material. That is, these theories assume that two materials with the same tensile yield or ultimate strengths but with different ductilities are equally satisfactory to the designer. In other words, the determination of the failure load for a pressure vessel should consider the plastic stress-strain behavior of the material to failure. This bulletin develops a theory for finding the wall thickness of a thin-walled cylindrical pressure vessel based upon the plastic range and so-called "instability" or maximum pressure that can be produced in the vessel. This bulletin extends the theory to nonisotropic materials. In addition, comparisons are made between available test results and theory. Comparisons with current design code requirements are also included. For certain materials, temperatures and states of combined stress, brittle type material behavior occurs with relatively small plastic deformations being produced prior to fracture. Failure under these circumstances is the brittle cohesive type of failure. Materials and conditions with this latter type of behavior are not included in the present discussion.

Single copies of this bulletin may be purchased at $1.00 per copy through the American Welding Society, 33 West 39th Street, New York 18, N. Y.

Quantity lots may be purchased through the Welding Research Council, 29 West 39th Street, New York 18, N. Y.

RECORD BRAZE-WELDING REPAIR ON 60-TON HAMMER BASE PREVENTS 8 MONTHS' LOSS OF PRODUCTION

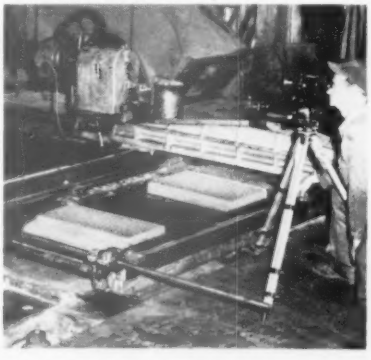


8,000-LB. FORGING HAMMER back in service after braze-welding repairs to its 120,000-lb. anvil, which extends 8 feet below floor level. Color shows location of repair weld.

PREPARING FRACTURED SURFACE of anvil to produce a smooth surface with overlap margin. Dotted lines show original outline.

ABOVE: Completed weld which used 2,350 lb. of Tobin Bronze-481 Welding Rod.

BELOW: A portable planer was used for finish-machining the repaired anvil.



When the 60-ton, semi-steel base of a big forging hammer at the Jessop Steel Co., Washington, Penn., fractured, management had to make a quick decision. Ordering a new base meant that the hammer would stand idle approximately nine months. Consultation with Maintenance Engineering Corp., of Pittsburgh, specialists in the repair of heavy machinery, showed that the base could be repaired by braze-welding at a big saving in time and money.

Maintenance Engineering got the go-ahead and completed the weld in one week*—a saving of eight months' production time—*at 20% of replacement cost.* "We are very pleased with the savings in down time and cash," says Mr. H. K. Taylor, Vice President in Charge of Operations of Jessop Steel Co. "The hammer has been back in service now for over six months and the braze metal is just an integral part of the base."

*Including preparation, machining and welding—total of 3 weeks.

Always consider braze-welding repair. No matter how bad or how big the break in industrial equipment, it pays to investigate the advantages of repairing it by braze-welding. The savings possible in production time and cost are often surprising. Oxyacetylene braze-welding with Anaconda-997 (Low Fuming) Bronze and Tobin Bronze*-481 Welding Rods is receiving increasing recognition as the easiest and least expensive method of making strong, lasting repairs. For more information and technical assistance on your welding problems, write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5696

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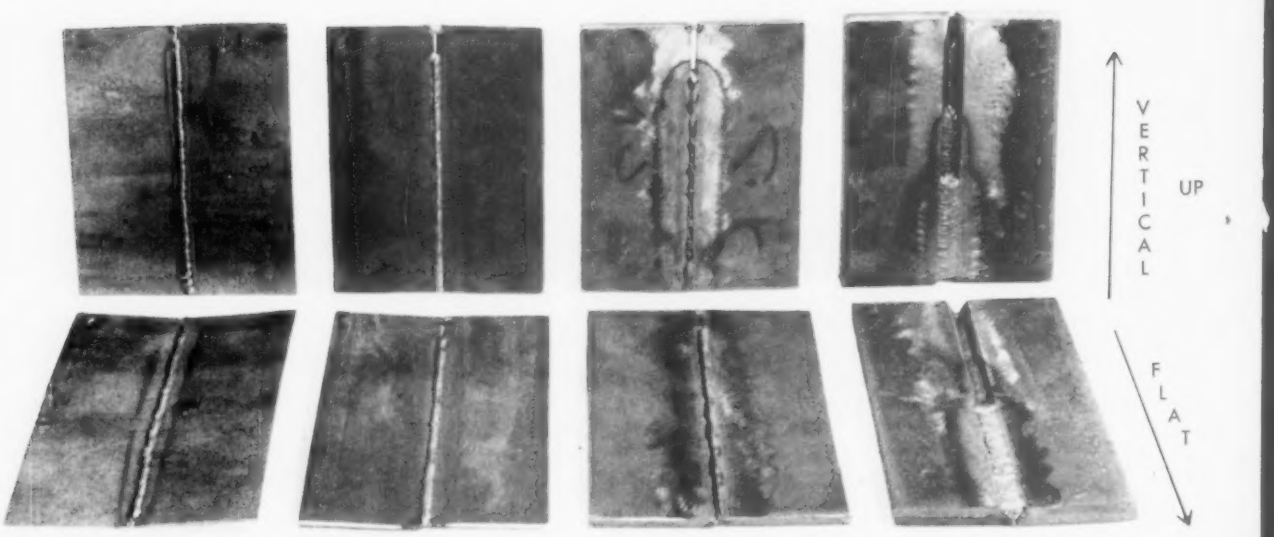
THIN to **THICK**



VERTICAL UP — $\frac{1}{4}$" sheet. Square butt. One pass. $\frac{1}{16}$" Root opening. Welding speed 10 IPM.

FLAT — $\frac{1}{4}$" sheet. Square butt. One pass. $\frac{1}{32}$" Root opening. Welding speed 10 IPM.

VERTICAL UP — $\frac{1}{4}$" plate. Square butt. One pass. $\frac{1}{16}$" Root opening. Welding speed 9 IPM.

FLAT — $\frac{1}{4}$" plate. Square butt. One pass. $\frac{1}{32}$" Root opening. Welding speed 10 IPM.

VERTICAL UP — $\frac{1}{4}$" plate. Square butt weld. One pass. $\frac{1}{16}$" Root opening. Welding speed 3.25 IPM.

FLAT — $\frac{1}{4}$" plate. Square butt weld. One pass. $\frac{1}{16}$" Root opening. Welding speed 2.1 IPM.

VERTICAL UP — $\frac{1}{2}$" plate. Single V butt weld. 60° included angle. Zero root opening. Pass ☰1, Stringer bead at 7 IPM. Pass ☰2, Full weave at 3.9 IPM. Pass ☰3, Full weave at 2 IPM.

FLAT — $\frac{1}{2}$" plate. Single V butt weld. 60° included angle. Zero root opening. Pass ☰1, Stringer bead at 9.6 IPM. Pass ☰2, Full weave at 4.1 IPM. Pass ☰3, Full weave at 2.1 IPM.

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